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# Corn-boring insects of Iowa: with special reference to the stalk borer, Papaipema Nebris (Gn) and the four-lined borer, Luperina Stipata (Morr)

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CORN-BORING INSECTS OF IOWA

WITH SPECIAL REFERENCE TO THE STALK BORER, _PAPAIPEMA NEBRIS_ (GN.) AND THE FOUR-LINED BORER, _LUPERINA STIPATA_ (MORR.).

BY

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## Introduction

Since the introduction of the European Corn Borer (*Pyrausta nubilalis* Hubner) into the United States there has been an increased interest in all insects which have the habit of boring in corn. Many of our native stalk borers, heretofore little known in literature but frequently of considerable local importance, are now receiving some measure of attention. Certain of these borers, for example the smartweed borer (*Pyrausta ainsliei* Hein.) and the lotus borer (*Pyrausta penitalis* Grote), are of interest because they so closely resemble the European Corn borer that differentiation between the species is difficult. Others, for example, the stalk borer (*Papaipema nebris* Gn.) and four lined borer (*Luperina stipata* Morr.) are corn pests of considerable importance and still others for example, the spindle worm, (*Achatodes zeae* Harris) and the lined-corn borer (*Oligia fractilinea* Grote) although of minor economic importance are frequently found in corn are occasionally confused with the other borers.

In view of the general interest in these borers, the large amount of confusion that exhists and the extensive damage done by two of the borers it was deemed advisable to make a thorough study of their bionomics.

The data presented in the following pages are the result of studies conducted during the years 1926-1929 inclusive.

## METHODS

The life history studies and experiments were conducted largely at Ames, Iowa, in a screened out-door laboratory.

Larvae were reared individually in shell vials and stender dishes. Thirteen by sixty mm. shell vials with cotton plugs were used for the first three instars, and sixty by thirty-five mm. stender dishes or three ounce crystal glass ointment jars, were used for the latter instars. Three ounce ointment jars with perforated aluminum tops were found to be most satisfactory for work with the larger caterpillars. Observations were easily made and the perforated lids permitted the free exchange of air preventing the accumulation of moisture and injurious gases. The larvae were examined daily, all molts were recorded and the food changed as needed, which was usually every second day. Larvae were collected in the field at weekly intervals to compare the development in the field with insectary rearing records.

Pupae were placed on moist, fine sand in the same type of ventilated jar as was used for mature larvae.

Shortly after emergence the moths were removed to modified Riley cages where their activities could be observed by placing a red electric light bulb near the side of the cage opposite the observer.

In order to determine the number of eggs laid by individual females, pairs of moths were placed in battery jars containing dead corn and grass leaves. These cages were examined daily and all eggs counted and removed. Other pairs were caged with both living and dead plants. The eggs were not counted until after the moths had died. Egg masses were left attached to the plants on which they were deposited and were kept in the outdoor laboratory during the winter months.

## THE FOUR-LINED BORER
*Luperina Stipata* (Morr.)

The first reference to the four-lined borer as a pest was made by F. M. Webster (52), who in 1889 reported it as doing serious damage to corn in various parts of Indiana, especially on low, recently drained and newly broken land. A year later (referring to his note of 1889) he wrote, "Since that notice was written, reports of serious depredations have come to me from Clinton, Miami, Madison and Johnson Counties, Indiana, all indicating that this is the most destructive of all cutworms in the localities where it occurs; some fields being totally ruined, and that, too, after it is too late in the season for replanting. Both low and high lands, timothy and clover sod seem alike attacked, even though the ground may have borne but one previous crop of grass or clover." Aside from these early reports by Webster there is little in literature concerning out-breaks of this species. Forbes (17) in his monograph on corn insects mentions the occurrence of the larva in Illinois but he says nothing concerning its economic importance in the state.

On June 18, 1927, the writer, accompanied by Dr. C. J. Drake, visited the Cris Teig farm near Randall, Iowa where the borer was found working in a field of corn. Most of the damage was confined to a low area near a prairie meadow which extended along one side of the field. On July 14, 1927 several specimens were received from Kossuth county where the borer was doing considerable damage in two corn fields. These infestations also occurred in fields adjacent to areas of natural prairie sod.

In 1928 and again in 1929 the borer reappeared at Randall and also in several counties in the northern part of the State. From one-half to two and one-half acres of corn were destroyed in each of the seven largest infestations examined. Most of the infestations, however, were small and only a few rows of corn along the margins of the fields were seriously injured. It would be difficult to estimate the total loss resulting from the numerous small infestations of this type.

DISTRIBUTION

Luperina stipata is a North American species and is generally distributed over the northeastern portion of the United States and part of Canada. It is definitely reported as occurring in New Brunswick, Maine, Massachusetts, New York, Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa and Colorado. The adult moths are quite rare in collections, due to the fact that they are infrequently attracted to lights and are very adept at concealment in the field. Hence, it is not improbable that this species occurs in regions outside of its present known range.

The borer is found thruout Iowa, but it is much more common in the north-central portion. The Iowa records are given in fig. 15.

HOST PLANTS

Field observations indicate that the common slough grass (*Spartina michauxiana* Hitchs.) is its natural host plant, as it is the only plant in which the borer has been consistently found. In the north-central part of the State practically every stand of *Spartina* of five square yards or larger was infested, and it might be added that nearly every one of the numerous small patches growing along fence rows was also infested. Very young borers have been taken in timothy (*Phleum pratense* L.), wild rye (*Elymus robustus* Scribn. and J. G. Sm.), sedge (*Carex* sp.), oats (*Avena sativa* L.) and corn (*Zea mays* L.) A few half-grown larvae were found feeding in the crowns of green foxtail (*Setaria viridis* L.) and Mexican drop-seed (*Muhlenbergia mexicana* L. Trin.). Corn is apparently the only cultivated plant that is commercially injured by the borer and so far as known is the ~~the~~ only plant other than *Spartina* in which the borer readily matures.

NATURE OF INJURY

The larva attacks its host in several different ways. On tender young plants the newly hatched larvae usually bore into the stem near the surface of the soil or crawl under the lowest leaf sheath and enter at that point. On larger and tougher plants they frequently climb up the plant and tunnel down into the "open heart." If the soil is loose or if there is a crevice in the ground near the plant, the borer frequently tunnels into the stem below the surface and just above the crown (fig. 3). Upon the death of their initial host, first, second and third instar larvae may enter a second host by one of the above mentioned ways. As the borers become older and larger the tendency to work below the surface of the soil prevails. Borers in the fourth and later instars invariably descend to the bottom of their burrows and then migrate underground to other plants. In this way a single borer sometimes destroys every plant in a hill of corn without coming to the surface of the soil.

Corn is usually attacked by half-grown larvae migrating from wild host plants. After entering below the surface of the soil they bore upward thru the "heart" and ultimately kill the plant. This mode of attack produces what is commonly known to the grower as "dead heart." (fig. 1f.) It is characterized by the central portion of the plant being dead while the outer leaves remain green and appear healthy. The tunnels form favorable avenues for the entrance of decay producing organisms, and the complete destruction of the plant is only a matter of a few days.

COMPARISON OF INJURY WITH THAT PRODUCED BY OTHER BORERS

Several species of insects are more or less commonly found to attack corn in such a way that the injury might easily be confused with that of the four-lined borer. The stalk borers, Papaipema nebris (Gn.) and P. cataphracta (Grote); the spindle worm, Achatodes zea (Harris); the lined corn borer, Oligia fractilinea Grote; the pale western cutworm, Porosagrotis orthogonia Morr.; the hop-vine borer, Hydroecia immanis Gn.; wire worms, Melanotus spp., and several other insects frequently cause "dead heart" in corn. The injuries produced by these insects may be so much alike that only a trained observer can distinguish them. The final determination, of course, frequently rests in the finding of borers.

The species most apt to be confused with Luperina stipata is the stalk borer (Papaipema nebris). The larva of the latter is white, marked with four longitudinal purplish brown stripes and a broad band of the same color around the middle of the body. It enters the plant above the soil line, and by burrowing upwards it destroys the central portion of the plant. It seldom works in that portion of the plant which is below the ground. In general appearance and method of attack P. cataphracta is very similar to this species.

The larva of the pale western cutworm is a dull, gray or greenish caterpillar, rather inconspicuously marked with fine greenish or greenish brown longitudinal stripes. This species almost invariably attacks the plant below the surface of the soil, and when not actually feeding the larva is usually to be found in the soil some few inches away from the plant. Ordinarily this species will be found on high, light soils, while the four lined-borer will be found on heavier low-land soils.

The larva of the spindle worm (<u>Achatodes zea</u>) is yellowish-white with head, thoracic and anal shields, glossy-black; each body segment is adorned with 12 to 14 prominent black tubercles. This species is common in elder-berry and occasionally attacks corn and other plants growing in close proximity. Injury to corn is very similar to that produced by <u>Papaipema nebris</u>.

The lined corn borer (<u>Oligia fractilinea</u>) and the hop-vine borer (<u>Hydroecia immanis</u>) are not often encountered in corn in Iowa. The former prefers to enter the "heart" of the plant from above, while the latter usually enters near the ground and burrows upward in the stem.

Wireworms (*Melanotus* and other genera) occasionally burrow into the side of the stem and kill the young corn plants. Several other species of insects, such as cut-worms, sod webworms, seed corn maggots, aphids and white-grubs, which work on the roots may kill the plant; but in these cases the whole plant wilts and dies, and such injury would not be confused with "dead heart."

Mention should be made of mechanical injury not because it resembles injury by the borer but rather because borer injury may be overlooked and passed as mechanical injury. (By mechanical injury is meant injury due to machines, wind or weather.) Very often infestations at the edge of the field go unobserved, and all of the damage is attributed to injuries resulting from cultural operations.

## SYSTEMATIC HISTORY AND SYNONYMY

1875 *Hadena stipata* Morrison. Proc. Acad. Nat. Sci. of Philadelphia, XXVII, p. 64.
1889 *Hadena stipata* Webster. Insect Life. II, p. 132.
1890 *Hadena stipata* Webster. Insect Life. II, p. 382.
1890 *Luperina stipata* Smith. U. S. Nat. Mus., XIII, p. 411.
1890 *Luperina (Hadena) stipata* Webster. Bul. U. S. D. A. Bur. Ent. 22, p. 47.
1893 *Luperina stipata* Smith. Bul. U. S. Nat. Mus. 44, p. 131.
1894 *Hadena stipata* Webster. Insect Life. VI, p. 146.
1901 *Hadena stipata* Beutenmuller. Bul. Am. Mus. Nat. Hist. XIV, p. 301.

1902 Hadena stipata Dyar. Bul. U. S. Nat. Mus., 52, p. 53.
1905 Hadena stipata Forbes. 23rd. Rept. of State Entomologist of Ill. p. 77.
1908 Luperina stipata Hampson. Cat. Lepid. Phal. VII, p. 468.
1916 Luperina stipata Barnes & McDunnough. Check List Lepid. N. Am., p. 63.

This species was described by H. K. Morrison (35) in 1875, as Hadena stipata, from a specimen sent to him by Mr. Thomas E. Bean of Illinois. Fifteen years later Smith (43) transferred stipata to the genus Luperina. Since that time stipata has been frequently changed from one genus to the other, due to the fact that differences of opinion as to generic types have led to considerable confusion in these and certain other noctuid genera. Recent workers, Hampson, Barnes, McDunnough and Heinrick, however, are agreed that stipata should be placed in the genus Luperina.

## COMMON NAME

Webster (53) and (54) has referred to this species as a cutworm, and Forbes (17) mentions it with other species of the genus under the caption "The Hadena Stalk Borers," but so far as the writer can find no specific common name has been applied to it. In as much as this insect is most frequently found as a characteristically striped, boring caterpillar it may be appropriately called the "four-lined borer."

## DESCRIPTIONS

### Egg

(Fig. 1., c.)

Oblate-spheroidal, circular in cross section, pearly white when laid but soon turning yellowish gray or pinkish; exochorion sculptured with approximately one hundred raised, longitudinal ridges; converging of ridges produces reticulated area around poles; micropyle located in the center of one flattened pole surrounded by rosette of pyriform cells.

Equatorial diameter .625 mm.; polar diameter .450 mm.

## LARVA

### First to fifth instars.

Head flattened, circular to obovate in outline, yellow with smoky shading; trophi brown; ocelli conspicuous, black, six on each side. Body moderately slender, cylindrical, tapering toward both extremities, except in newly hatched and recently molted individuals, which taper gradually from head to anal extremity. Thoracic shield broad, undivided, smoky yellow to fuscous, darker near the cephalic and lateral margins; anal shield smoky yellow, darker near margins, with five spines on the caudal margin. Legs and prolegs normal (however, young larvae frequently move with a looping movement similar to that of geometrid larvae); spiracles with dark brown or black borders and pale centers; eighth abdominal spiracle larger and higher than the others. Newly hatched larvae pale yellowish white, slightly dusky caudad, often with a pinkish or greenish tinge. Characteristic color pattern evident in all instars. Ground color of body yellowish white; body segments from mesothoracic to the ninth abdominal inclusive marked with four broad, reddish-brown, longitudinal stripes; two subdorsal stripes separated by a narrow dorsomedian line of yellowish-white; a broad irregular, somewhat broken and apparently double, lateral stripe on each side just above the spiracles; also a light, double sublateral stripe, extending from the first to the ninth abdominal segments just above the base of the prolegs; ventral surface yellowish white.

Head capsule measurements for each instar are shown in table I.

Table I. Larval head capsule, widths in Mm.

| | Instars | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| Theoretical | .316 | .478 | .725 | 1.09 | 1.66 | 2.52 | |
| Six instar larvae | .315 | .470 | .720 | 1.10 | 1.65 | 2.42 | |
| Seven instar larvae | .315 | .469 | .718 | 1.07 | 1.57 | 2.04 | .58 |

Sixth instar (fig. 1.d.)

Head rounded, slightly bilobed, quadrate to obovate in outline, yellowish, faintly mottled with fuscous; trophi brown; ocelli, six on each side, black, III, IV and V larger than I, II and VI (fig. 9). Epistoma with normal setae ($E^1$, $E^2$); the distance between $E^2$ on either side more than twice that between $E^1$ and $E^2$. Frontal punctures ($F^a$) very close together and immediately between frontal setae ($F^1$), near lower margin of frons. The distance between $F^1$ and $Adf^1$ greater than the distance between $Adf^1$ and $Adf^2$; $Adf^2$ well behind beginning of LR. Adfrontal puncture ($Adf^a$) slightly anterior to beginning of LR; closer to $Adf^2$ than to $Adf^1$. Anterior setae ($A^1$, $A^2$ and $A^3$) forming a slightly obtuse angle; $A^2$ short, about equidistant from $A^1$ and $A^3$; $A^1$ and $A^3$ long. Anterior puncture ($A^a$) equidistant from, and slightly above a line connecting $A^2$ and $A^3$. Posterior setae ($P^1$, $P^2$) long; $P^1$ laterad and slightly posterior of $Adf^2$; $P^2$ posterior to $P^1$; the distance between $P^1$ and $P^2$ equal to the distance between $P^1$ and $Adf^2$; a line connecting $P^1$ and $P^2$ approximately parallel to LR. Posterior punctures two; $P^a$ nearer to $L^1$ than to any other seta, lying between $L^1$ and $Adf^2$; $P^b$ close to and slightly latero-ventrad of $P^2$. Lateral seta ($L^1$) remote from $P^1$ and $A^3$ with which it forms a right triangle, $L^1P^1$ being perpendicular to $L^1A^3$. Lateral punctures ($L^a$) remote posteroventrad of $L^1$. Ocellar setae ($O^1$, $O^2$, $O^3$) well separated; arranged in the form of an isosceles triangle ($O^1O^3$ being equal to $O^2$ $O^3$); $O^1$ ventrad of ocellus IV; $O^2$ postero-ventrad of ocellus I; $O^3$ remote, postero-ventrad of ocellus VI. Ocellar puncture ($O^a$) lying between $O^3$ and ocellus V but nearer to the seta than to the ocellus. Genal seta ($G^1$) remote, posteroventrad of $O^3$. Genal puncture ($G^a$) antero-dorsad of $G^1$. Subocellar setae ($SO^1$, $SO^2$, $SO^3$) triangularly placed, $SO^2$ very close to ocellus V. Subocellar puncture ($SO^a$) equidistant between $SO^1$ and $SO^3$.

Body cylindrical, moderately stout, tapering towards both extremities, without secondary hairs, dirty white in color, with characteristic color markings of earlier instars only faintly discernible; legs and prolegs normal. Chrochets uniordinal and arranged in a mesoseries. Prothoracic shield broad, undivided, yellowish, more or less smoky, with small area of pigmented granules between $I^b$ and $II^b$. Spiracles oval, black with brown centers; eighth abdominal spiracle slightly larger and higher than the others. Anal plate yellowish with five reddish brown spines on its posterior margin. Body setae pale yellow to amber, moderately long; tubercles inconspicuous, not strongly chitinized. (fig. 8.)

Prothorax: $I^a$, $I^b$, $II^a$, $II^b$ and $II^c$ on the shield; the two former on the cephalic margin, the three latter on the caudal margin; $I^c$ absent (or $I^c$ may be represented by the puncture on the shield close to $II^c$); IV and V approximate and on a single chitinization chephalad of the spiracle; VI bisetose, ventrad of IV and V; VII represented by a number of setae at the base of the leg; VIII caudo-ventrad of the leg.

Mesothorax and metathorax: $I^a$ near the dorsomeson, $I^b$, $II^a$ and $II^b$ almost in line and successively ventrad of $I^a$; III caudo-ventrad of $II^b$; IV dorso-cephalad of III; V cephalo-ventrad of IV; VI directly ventrad of $II^b$, remote; VII and VIII as on prothorax.

First and second abdominal segments: I near dorsomeson; II caudo-ventrad of I; III directly dorsad of the spiracle; $III^a$ cephalo-ventrad of III but cephalo-dorsad of spiracle; IV caudad of the upper corner of the spiracle; V ventrad of the spiracle; VI caudo-ventrad of V, remote; VII cephalo-ventrad of VI, bisetose on first and trisetose on second segments; VIII ventrad and slightly caudad of VII group.

Third to sixth abdominal segments same as preceding, except VII is situated on outer face of proleg and VIII on its inner face.

Seventh abdominal segment: I, II, III, $III^a$, V and VIII as before; IV dropped to a point caudo-ventrad of spiracle; VI moved forward and directly ventrad of V; VII unisetose, caudo-ventrad of VI.

Eighth abdominal segment: I as before; II caudad and slightly ventrad of I; III cephalo-dorsad of spiracle; $III^a$

directly cephalad of spiracle; IV caudad of spiracle; V ventrad and slightly cephalad of spiracle; VI caudo-ventrad of V; VII unisetose, directly ventrad of spiracle; VIII ventrad of VII.

Ninth abdominal segment: II near the dorsomeson; I cephalo-ventrad of II; III saml1, ventrad, remote and slightly caudad of II; IV, VII and VIII in line and successively ventrad III.

Tenth abdominal segment: four prominent setae on each half of plate; numerous short setae around base of proleg.

Head width, 2.34 to 2.80 mm. Average of 100, 2.52 mm.

Length of body, 23 to 31 mm. Average of 50, 28 mm.

PUPA
(Fig. 1, e.)

Typical noctuid pupa; (fig. 11) labrum separated from clypeus by distinct suture, labial palpi visible, about one-fourth length of maxillae; mesothoracic wings reaching nearly to ventro-caudal margin of fourth abdominal segment. Maxillae prominent, reaching almost to tip of wings. Prothoracic legs slightly more than half as long as maxillae, prothoracic femur exposed; mesothracic legs slightly longer than antennae, nearly as long as maxillae; metathoracic legs exposed caudad of maxillae, extending to tip of wings. Abdominal segments gradually tapering; dorso-cephalic margins of abdominal segments four, five, six and sevem marked with many small, chitinized, circular pits; pit markings extending to ventral surface of segments five, six and seven but fewer in number and less prominent; spiracles (except eight abdominal) ellipsoidal, dark brown; eighth abdominal spiracle reduced to slit-like opening; prolegs scars absent; larval setae and setal arrangement largely retained; cremaster short, ending in two straight (or slightly curved) sharp spines; color varying from very light to dark brown (according to age); genital opening of female simple, slit-like, cephalad of eighth abdominal spiracle, cephalic margins of segments nine and ten curved forward towards genital opening; genital opening of male simple, slit-like, on a slight elevation, caudad of eighth abdominal spiracle, on ventro-caudal margin of ninth abdominal segment.

Length 18 to 23 mm.; greatest width 6 to 7 mm.

ADULT
(Fig. 1, a and b.)

Female: Head and thorax ochraeus gray, suffused with fuscous brown; eyes large, rounded; frons smooth; palpi upturned, third joint short, oblique, sides more or less blackish. Prothoracic and metathoracic crests divided, a transverse black band extending across front of prothoracic crest. Legs grayish fuscous to blackish; tibia moderately fringed with hair, tarsi dark, often with light rings. Fore wings (fig. 10) rather narrow, pale fuscous, suffused with purplish brown, especially along costal margin; distal portion of cubitus and base of $M_3$ and $Cu_1$ veins white, black defined by ochreous white beyond transverse posterior band; other veins dark often black; subbasal and transverse anterior bands reduced to few black scales or obsolete; transverse posterior band faint to obscure, indistinctly double, margins black, center white, indistinct in radial cells, outwardly oblique to $M_3$, inwardly oblique from $Cu_1$ to near 2nd A., thence straight or indefinite to margin; subterminal band faint, white inner margin outlined by black, indistinct to $M_3$, inwardly oblique from $Cu_1$, to center of $Cu_2$ cell, then curved slightly out to meet 2nd A. at margin; terminal line represented by a series of black lunules between veins; claviform replaced by broad black fascia in Cu cell from t. a. to t. p.; obicular small, irregular, defined by black, absent in some specimens; reniform small, upright, irregular, light to fuscous center outlined by black, rest at union of $M_3$ and $Cu_1$ veins, sinuous black streak below base of cell; undulating black streak in cell $A_2$, before t. a.; terminal space dark fuscous; triangular black area covering $M_3$ cell and distal portions of $M_1$ and $R_5$ cells. Hind wing dirty white, slightly darker near tremen; underside of both wings dirty white irrorated with brown; abdomen dirty white tinged with brown towards extremity, lateral fringe of hairs but no distinct lateral tufts.

Male: Similar to female, usually slightly lighter in color. Antennae ciliated, the anal tuft more or less bushy or fan shaped. Expanse, 28 to 40 mm.

## LIFE HISTORY AND HABITS

### Egg

The normal length of the egg stage is about eight and one-half or nine months. Eggs which are deposited between July 15 and the last of August do not hatch until the following spring, usually during the latter part of April. Hatching dates for 1928 and 1929 were identical, beginning April 16, and extending to April 30, with a maximum hatch April 22. It appears that the length of the egg stage may be exceedingly variable under different conditions of temperature and humidity.

Development: Some embryological development takes place during the first few days after egg deposition, but in a few days growth ceases and the eggs remain in a partially developed condition until spring or until after a suitable exposure to some reactivating or accelerating agent such as low temperature. Eggs laid July 15 and kept at a temperature of 27°C. and at 80 per cent relative humidity did not hatch and at the end of nine months were apparently all dead. Other eggs which were laid the same day but which were later subjected to temperature below the threshold of development, or minimum effective temperature, for one month or longer developed normally when replaced under conditions favorable to incubation. In this way the length of the egg stage can be shortened from nine months to forty-five days.

## LARVA

Newly hatched larvae appear during the latter part of April or the first part of May, which is about the same time that our earliest grasses are sending up their first shoots. During the last week in April, when hatching was at its peak, blue grass, timothy, sedge, Mexican dropseed, wild rye and slough grass were making fair growth while fox tail and some of the other grasses had not started. This would indicate that the young larva fed for a time on some of these early grasses.

GENERAL HABITS: Hatching may occur at any time of the day or night, but as a rule larvae hatching during the day remain concealed under a leaf sheath or in some other suitable place until evening before starting to search for food. In some instances the larvae devour the shells from which they have issued and a few have also been observed to eat parts of dead stems and leaves, but the majority do not feed until they have found fresh green plants. When a suitable plant is found very hungry individuals will begin at once to eat the epidermis of the leaves, whereas others will crawl about and explore one or more plants before settling down to feed. Usually only one borer can be found in a plant. As has been mentioned in discussing the nature of injury, larvae may attack young plants by one of three different methods. The initial host may be killed in two or three days, or the plant may be large enough to survive for a week, but in any case as soon as a plant is killed the larva migrates to another plant. Larvae in the first four instars may move about above ground more or less freely, but those in one of the last three instars always enters the plant below the surface of the ground. The latter usually construct an elongated tube or tunnel just beneath the surface of the ground, which extends from the entrance hole to a point two or three inches from the plant. When not feeding the larva usually will be found resting in this retreat. Excrement and castings from the feeding burrow in the plant are packed into the far end of this underground tunnel, and if it becomes nearly filled a side branch or a new tunnel is formed.

The ability of the newly hatched larvae to withstand adverse conditions is remarkable. Larvae die and shrivel quite rapidly at high temperatures especially when they are accompanied by low humidities, but since hatching occurs at a time when these conditions are not prevalent, newly hatched larvae have been known to live without food for from 48 to 72 hours, during most of which time they were active and crawling about in their cages. The fact that first instar larvae which were left out-of-doors when the temperature dropped to 26°F. were not injured, and the fact that young larvae feeding on grass and corn developed normally though subjected to freezing temperatures on several successive nights, led to further studies on the effects of low temperatures such as might occur during late April. Newly hatched larvae unfed and kept at 11°C. lived for from 2 to 15 days, others kept at 0°C. lived for from 8 to 37 days, and still another lot kept at low temperatures which varied between 0 and -16°C. lived for from 2 to 30 days. Second instar larvae which were almost ready to molt were subjected to the same tests and found to be almost as hardy as the unfed individuals. The results of these experiments are summarized in table II.

During the course of these experiments it was noted that the larvae became very sluggish at temperatures below 8°C. and that they became inactive at 5°C.

Newly hatched and unfed larvae react positively to light and negatively to the force of gravity. After they reach their host plants these reactions are not so noticeable, and as the larvae become older they are practically reversed.

ECDYSIS: Several days after hatching when the larva has increased in length by about 50 per cent, it stops feeding and becomes more or less inactive. A prominent, white, swollen area which appears between the head and the prothorax continues to enlarge until the outer cuticle ruptures. Then by a series of violent contractions the old "skin" is worked back over the body and the old head capsule is moved forward off of the head. This is the first molt and the end of the first stadium.

TABLE II. SHOWING THE EFFECT OF LOW TEMPERATURE ON THE LENGTH OF LIFE OF NEWLY HATCHED AND SECOND INSTAR LARVAE.

| Temperature in ° Centigrade | Number of days | | | | | | |
|---|---|---|---|---|---|---|---|
| | Newly hatched larvae | | | | Late 2nd instar larvae | | |
| | -16* to 0 | 0 | 11 | 15 | -16* to 0 | 0 | 11 |
| Minimum | 2 | 8 | 2 | 1 | 1 | 5 | 1 |
| Maximum | 30 | 37 | 15 | 5 | 20 | 35 | 9 |
| Average | 18 | 26.3 | 10.7 | 2.7 | 7.4 | 24 | 7.2 |
| Number of specimens | 25 | 100 | 100 | 75 | 10 | 25 | 20 |

*Temperature fluctuating between 0 and -16°C.

INSTARS: Altho subject to considerable variation the number of instars characteristic of this species is apparently six. However, larvae having more than six instars are quite common. When the rate of growth is reduced by abnormal temperatures, poor food or other unfavorable conditions the larvae continue molting at regular intervals with little or no increase in size, and in extreme cases there may be a slight reduction in size. The larvae of one series which were purposely given poor food had from seven to eleven molts, and about one-third of them never reached the pupal stage but died after they had molted eight or nine times. During the 1929 season the following experiments were conducted to determine the effects of using various parts of the corn plant as food for the larvae. In each case 25 larvae were used.

EXPERIMENT

A. Larvae were fed basal portion of rapidly growing young corn plants.

B. Food as in experiment A.

C. Larvae were fed middle portion of stalk from rapidly growing young corn plants.

D. Food as in experiment C.

E. Larvae were fed the upper portion of the stalk of rapidly growing young corn plants. (This portion consists largely of closely rolled leaves.)

F. Food as in experiment E.

G. Larvae were fed leaves from rapidly growing young corn plants. (Part fed was taken from leaf blade 2 to 4 inches above rolled portion at base.)

H1. Larvae were fed basal portion of stalk from corn in tassel. (Stalk was somewhat woody.)

I. Larvae were fed basal portion of stalk from corn setting ears. (Stalk was quite woody.)

It was found that the larvae which were fed succulent stalks of young corn made more rapid growth and completed their development with a smaller number of instars than the larvae which received less desirable food. A and B produced a predominance of six-instar individuals with a few larvae having seven instars.

C. and D produced only seven-instar individuals.

E and F produced a few seven-instar individuals but the majority required eight instars.

G. All of these larvae died in or before the ninth instar.

H and I produced individuals having nine or ten instars and six individuals died in the eleventh instar.

The results of these experiments are presented graphically in fig. 12.

A study of table I reveals that the head capsule measurements of the six-instar individuals are in close agreement with the theoretical dimensions calculated by the application of Dyar's law. (13). It should be further noted that measurements for the seven instar individuals are in close agreement with the others up to the fifth molt, where the normal rate of increase is greatly reduced as if by some retarding influence. This retardation of growth may have been due to the fact that the corn stalks had become hard and more or less woody, and also due to the fact that the larvae were forced to make more frequent migrations.

If we consider the number of molts required under the most favorable food conditions as indicating the normal tendencies of the species, then any increased number of molts are to be considered as variations brought about by an unfavorable environment.

Ripley (40) and others have shown that with some Lepidoptera changes in temperature and humidity may increase or decrease the number of molts by one. However, in the case of Luperina stipata no such effects were noted. Larvae which were fed succulent stalks of young corn were reared at the following constant temperatures: 13°, 23°, 27° and 33°C. The humidity in the larval burrows within the stalks may be considered constant. Practically every one of these larvae completed its development in seven instars. A few individuals reared at 33°C. showed slight retardation, and two of them required eight instars, but these variations were obviously due to the drying out of the food at that temperature, which could not be prevented. Two of the 45 individuals reared at 13°C. required only six instars. This may or may not be attributed to the fact that the food kept much fresher at the lower temperature. The results of these experiments are shown graphically in fig. 13.

The graph shows that despite the large range of temperatures there are no marked variations in the size of the respective instars, and that the various curves are not arranged consecutively so as to indicate a temperature relationship. It seems entirely possible that all of the variation in number of molts could be attributed to lack of uniformity in the food.

There is a slight tendency toward a sexual difference in the number of molts. A greater percentage of females than males presents an increased number of molts.

DURATION OF STADIA AND LENGTH OF LARVAL LIFE: The length of each individual stadium depends primarily upon the temperature while food and other conditions are of secondary importance. At relatively high temperatures larvae are very active, they feed voraciously and grow rapidly, but when the temperature drops activity and growth are retarded.

Larvae reared in an incubator at 27°C. developed almost twice as fast as those reared at 20°C., about two and one-half times as fast as those reared in the screened laboratory and about four times as fast as those reared at 13°C. A graphic presentation of these facts is given in fig. 14. The curves presented show that there is a marked uniformity in the proportionate length of the respective stadia, and that the length of any particular stadium is a variable which is directly correlated with variations in temperature. Figure 14 also shows, as do tables VI, VII and VIII that the second stadium is shorter than the first, and the stadia after the second become successively longer up to the seventh, which is the longest, except in individuals having more than seven molts, in which case the seventh stadium is shortened and the last stadium becomes the longest. Under natural field conditions as shown in tables III, IV and V this uniformity of development may be overshadowed by variations in temperature. In 1928 the mean temperature for May was 2.5°F. above normal while the mean temperature for June was 4.8° F. below normal. As a result the second and third stadia were abnormally long. In 1929 the conditions were reversed. The mean temperature for May was 2.4°F. below normal (4.9° lower than 1928) while the mean temperature for June was only 1.7°F. below normal (3.1° higher than in 1928). As a result the early stadia were lengthened and later stadia shortened. Furthermore the occurrence of warm and cool periods materially affected the length of individual stadia, eg., V and VI in table IV.

Variable or alternating temperatures tend to increase the rate of larval development. Two lots of larvae which were alternately exposed for 8 hours at 13°C. and 16 hours at 27°C. and two additional lots alternately exposed for

TABLE 3. DEVELOPMENT OF SIX INSTAR LARVAE IN SCREENED INSECTARY.

| | Number of days in each stadium | | | | | | Total days in larval stage |
|---|---|---|---|---|---|---|---|
| 1928 | I | II | III | IV | V | VI | |
| Minimum | 8 | 5 | 6 | 7 | 13 | 18 | 70 |
| Maximum | 17 | 8 | 8 | 11 | 23 | 28 | 78 |
| Average | 12 | 6.5 | 6.5 | 9 | 19 | 24 | 75 |
| Specimens | 39 | 39 | 39 | 39 | 39 | 39 | 39 |
| 1929 | | | | | | | |
| Minimum | 13 | 6 | 7 | 6 | 11 | 14 | 68 |
| Maximum | 17 | 10 | 11 | 10 | 19 | 21 | 79 |
| Average | 14 | 8.5 | 9.5 | 8.0 | 15 | 17 | 72 |
| Specimens | 37 | 37 | 37 | 37 | 37 | 37 | 37 |

TABLE 4. DEVELOPMENT OF SEVEN INSTAR LARVAE IN SCREENED INSECTARY

| | Number of days in each stadium | | | | | | | Total days in larval stage |
|---|---|---|---|---|---|---|---|---|
| 1928 | I | II | III | IV | V | VI | VII | |
| Mimimum | 9 | 5 | 5 | 7 | 10 | 9 | 20 | 78 |
| Maximum | 17 | 8 | 9 | 14 | 14 | 13 | 26 | 88 |
| Average | 12 | 6.5 | 6.5 | 9.2 | 12 | 10.5 | 24 | 81 |
| Specimens | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| 1929 | | | | | | | | |
| Mimimum | 11 | 6 | 6 | 5 | 7 | 9 | 14 | 72 |
| Maximum | 17 | 10 | 11 | 9 | 12 | 13 | 21 | 82 |
| Average | 14 | 8 | 9 | 7 | 10 | 11 | 17 | 75 |
| Specimens | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 |

TABLE 5. Development of Eight Instar Larvae in Screened Insectary.

| | Number of days in each stadim | | | | | | | | Total days in larval stage. |
|---|---|---|---|---|---|---|---|---|---|
| 1928 | I | II | III | IV | V | VI | VII | VIII | |
| Minimum | 10 | 5 | 5 | 7 | 9 | 8 | 9 | 17 | 82 |
| Maximum | 16 | 8 | 9 | 13 | 13 | 13 | 15 | 24 | 96 |
| Average | 12 | 6.5 | 6 | 9.5 | 11.5 | 11 | 12 | 20 | 88 |
| Specimens | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | |
| 1929 | | | | | | | | | |
| Minimum | 12 | 5 | 6 | 5 | 8 | 8 | 8 | 13 | 80 |
| Maximum | 16 | 9 | 11 | 11 | 12 | 11 | 14 | 23 | 93 |
| Average | 14 | 8 | 9 | 7.5 | 10 | 9 | 11 | 18 | 86 |
| Specimens | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |

TABLE 6. DEVELOPMENT OF SIX INSTAR LARVAE AT 27°C.

| | No. of days in each stadium | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | |
| Minimum | 3 | 2 | 2 | 2 | 4 | 12 | 29 |
| Maximum | 4 | 5 | 4 | 5 | 12 | 19 | 34 |
| Average | 3.6 | 2.5 | 3 | 3.8 | 7.0 | 13 | 31 |
| Specimens | 21 | 21 | 21 | 21 | 21 | 21 | 21 |

TABLE 7. DEVELOPMENT OF SEVEN INSTAR LARVAE AT 27°C.

| | No. of days in each stadium | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | |
| Minimum | 3 | 2 | 2 | 3 | 3 | 5 | 10 | 33 |
| Maximum | 4 | 4 | 4 | 5 | 5 | 8 | 18 | 41 |
| Average | 3.6 | 2.5 | 3.0 | 3.7 | 4.5 | 6.4 | 13.0 | 36.6 |
| Specimens | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 |

TABLE 8. DEVELOPMENT OF EIGHT INSTAR LARVAE AT 27°C.

| | No. of days in each stadium | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | |
| Minimum | 3 | 2 | 2 | 3 | 3 | 4 | 6 | 11 | 38 |
| Maximum | 4 | 4 | 4 | 5 | 6 | 7 | 9 | 16 | 45 |
| Average | 3.5 | 2.5 | 2.1 | 3.7 | 4.5 | 5 | 7 | 14 | 42 |
| Specimens | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

16 hours at 13°C. and 8 hours at 27°C. passed thru each of their respective instars and completed their larval development in approximately 89 per cent of the estimated time. Table IX, showing the comparative rates of development, is figured upon the basis of the first five stadia to avoid complications arising from the subsequent variability in the number of molts and length of stadia. It might be stated, however, that the calculations for each individual stadium and for the total length of larval life for six and seven instar larvae give the same results, i. e., a 10 or 11 per cent increase in rate of development in favor of the alternate temperatures.

TABLE IX. SHOWING COMPARATIVE EFFECTS OF CONSTANT AND ALTERNATING TEMPERATURES UPON THE RATE OF LARVAL DEVELOPMENT UP TO THE FIFTH ECDYSIS.

| Temperature hours per day at | | | Time Equivalent days at | | Velocity* coef. multiplied by time. | | Calculated development totals | Actual development totals | Per cent increase in rate of development. |
|---|---|---|---|---|---|---|---|---|---|
| 27° | 13° | Total days | 27° | 13° | 27° | 13° | | | |
| 24 | | 17.5 | 17.5 | | .9975 | | .9975 | 1.000 | |
| | 24 | 66.6 | | 66.6 | | .9999 | .9999 | 1.000 | |
| 8 | 16 | 30.9 | 10.3 | 20.6 | .5871 | .3090 | .8961 | 1.000 | 10.39 |
| 16 | 8 | 20.5 | 13.67 | 6.83 | .7791 | .1024 | .8816 | 1.000 | 11.84 |

*The velocity coefficients (1/T) were: 0.015 at 13°C., and 0.957 at 27°C.

Evidence that food conditions are of minor importance in determining the length of stadia was discovered in the variable food experiments previously mentioned. It was found that regardless of the type of food or the per cent of increase in size as determined by the successive head capsule measurements, the length of the individual stadia remained constant. However, it must be noted that the total length of the larval period may be materially increased by unfavorable food conditions. This is due to the fact that the number of instars required to complete development is increased.

By comparing table III with IV and V and table VI with VII and VIII it may be seen that the larval period is somewhat lengthened as the number of molts is increased. Under field conditions the length of the larval period varies from 68 to 78 days for six-instar larvae, from 72 to 88 days for seven-instar larvae and from 80 to 111 days for larvae having more than seven instars.

A COMPARISON OF INSECTARY RECORDS WITH FIELD RECORDS: Larvae were collected from the field at weekly intervals and their stage of development recorded as a check against the data secured from individuals reared under insectary conditions. Table X is presented to show the close correlation that exists between the two sets of data. It will be noted that the head capsule measurements

TABLE 10. DEVELOPMENT OF FIELD COLLECTED AND INSECTARY REARED LARVA COMPARED. 1928

| Date | Ave. Width of head capsule (mm.) | | Percent of individuals in each instar | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Field collected larvae | | | | | | Insectary reared larvae | | | | | | |
| | F.C. | I.R. | I | II | III | IV | V | VI | I | II | III | IV | V | VI | VII |
| Apr. 30 | .315 | .313 | 100 | | | | | | 100 | | | | | | |
| May 7 | .474 | .491 | 12 | 88 | | | | | 4 | 92 | 4 | | | | |
| May 14 | .738 | .750 | | 13 | 87 | | | | | 2 | 96 | 2 | | | |
| May 21 | .995 | 1.01 | | | 11 | 89 | | | | | 4 | 96 | | | |
| May 28 | 1.61 | 1.65 | | | | 9 | 91 | | | | | | 100 | | |
| June 4 | 1.65 | 1.73 | | | | | 85 | 15 | | | | | 83 | *17 | |
| June 11 | 1.79 | 1.86 | | | | | 44 | 56 | | | | | 46 | *54 | |
| June 18 | 2.34 | 2.50 | | | | | | +100 | | | | | | °46 | 54 |
| June 25 | 2.49 | 2.50 | | | | | | +100 | | | | | | °46 | 54 |
| July 2 | 2.44 | 2.50 | | | | | | +100 | | | | | | °46 | 54 |
| July 9 | 2.45 | 2.58 | | | | | | +100 | | | | | | °46 | 54 |

F. C.: Field collected
I. R.: Insectary reared
+VI and VII instar larvae can not be separated accurately.
*Not last instar.
°Last instar.

and stages of development of the two lots of larva are practically identical.

PREPARATION FOR PUPATION: When a larva becomes full grown it usually deserts the plant and its old retreat burrow and forms a rather small oval pupal cell just below the surface of the soil. In slough grass sod this cell is often so close to the surface that only a thin layer of leaf mulch is left to cover it. When the cell is completed the larva passes into the prepupal stage (fig. 6) in which the body contracts longitudinally, the thorax becomes curved whereby the head is thrown forward almost to the legs which are stiff and functionless. After spending from one to five days in this condition the insect sheds its last larval skin and the pupa is revealed.

## PUPA

Pupation occurs over a period of about a month beginning usually the last week of June and continuing well toward the end of July. The earliest date of pupation, June 26, and the latest, July 29, both occurred during the 1929 season (table XI). Immediately after transformation the pupa is white in color but within a few hours the wing pads and ventral portion of the body become yellow and dorsal portion reddish brown. In the next few days the color gradually changes to amber. About the fourteenth day four characteristic dark lines (part of the adult color pattern) appear in the wing pads, and within the next three or four days the color changes to dark brown or black in conformity with the color pattern of the adult , w ich emerges in one or two days.

Table XI. Date of Pupation. Summary.

| Year | First | Last | Modal average |
|---|---|---|---|
| 1927 | June 28 | July 16 | July 6 |
| 1928 | June 30 | July 23 | July 7 |
| 1929 | June 26 | July 29 | July 5 |

The duration of the pupal stage is quite variable and is influenced greatly by prevailing temperatures and to some extent by a number of other factors. The mean daily temperature during the pupal period in 1928 was two degrees lower and in 1929 three degrees lower than in 1927, and as a result the pupal period was prolonged. This is shown in table XII. An analysis of pupal records showed that in many instances individuals which had pupated on the same day and which had been kept under the same conditions (sometimes in the same container) showed variations of from one to five days in the duration of their pupal stages. These variations are not due to sex differences, for very often the first and last individuals to emerge were of the same

TABLE XII. PUPAL PERIOD.

| No. of: days | 1927 Male | 1927 Female | 1928 Male | 1928 Female | 1929 Male | 1929 Female |
|---|---|---|---|---|---|---|
| 12 | | 1 | | | | |
| 13 | | 1 | | | | |
| 14 | | 1 | | | | |
| 15 | 1 | 1 | | | | |
| 16 | 2 | 3 | | | | |
| 17 | 1 | 5 | | 5 | | |
| 18 | 2 | 1 | 11 | 8 | | |
| 19 | 2 | 1 | 20 | 12 | 1 | 1 |
| 20 | 1 | | 17 | 12 | 4 | 7 |
| 21 | 1 | | 16 | 19 | 7 | 13 |
| 22 | | | 12 | 7 | 17 | 10 |
| 23 | | | 1 | 2 | 10 | 6 |
| 24 | | | | | 2 | 3 |
| Total: | 10 | 14 | 77 | 65 | 41 | 40 |
| Average: duration | 17.90 | 16.00 | 20.01 | 19.94 | 21.90 | 21.55 |

sex. The records indicate that the length of the larval stage, especially the last instar, may have a slight influence on the length of pupal stage, but this factor alone does not explain differences as large as four and five days.

ADULT

EMERGENCE: At the end of the transformation period the pupa by a series of violent contortions makes an opening thru the top of its chamber. Then the anterior end of the pupal case is slit across the vertex and along the margins of the wing sheaths so as to permit the adult to make its exit. The wings, which at first appear very small and distorted, gradually expand. First they become somewhat convex, then more or less balloon-like and finally straighten out into their normal shape. During the next 30 or 40 minutes the fully expanded wings are held vertically over the back to dry, after which time they are dropped into their normal position over the back and the moth is ready for its initial flight. As is indicated in table XIII the time required for the whole operation of emergence varies from 44 to 57 minutes.

Most of the moths emerge at night, but a few have been observed to come out during the late afternoon. It seems probable that falling temperature such as occur during the late afternoon and evening stimulate emergence, and that temperatures between 70° and 75° F. are optimum. On July 24, 25 and 26, 1928, observations were made to determine the hour at which the peak of emergence occurred. The

TABLE XIII. RECORDS ON THE TIME OF EMERGENCE OF ADULTS. (1928).

| Date | No. of specimens | Splitting of pupal case | Free from pupal case | Wings expanded | Ready for flight | Total Time |
|---|---|---|---|---|---|---|
| 7-25 | 1 | 10:15 p.m | 10:17 p.m | 10:45 p.m | 11:03 p.m | 48 min. |
| 7-26 | 1 | 9:40 p.m | 9:45 p.m | 10:00 p.m | 10:37 p.m | 57 min. |
| 7-26 | 1 | 10:43 p.m | 10:50 p.m | 11:13 p.m | 11:27 p.m | 44 min. |
| 7-26 | 1 | 11:01 p.m | 11:05 p.m | 11:27 p.m | 11:50 p.m | 49 min. |
| 7-26 | 1 | 11:09 p.m | 11:15 p.m | 11:41 p.m | 12:01 a.m | 52 min. |

results of these observations (table XIV) indicate that the hours of emergence are variable but that the peak will usually occur soon after the temperature drops below 75°. In this connection it is interesting to note that on three different nights when the temperature failed to drop below

75°, the number of moths which emerged was low, while in each case the number which emerged the following night was abnormally high. Emergence during the cooler portions of the night seems to favor self-preservation because moths attempting to emerge at high temperatures and low humidities are frequently badly deformed.

The dates of adult emergence are shown in table XV.

TABLE XIV. SHOWING THE EFFECT OF TEMPERATURE ON THE TIME OF ADULT EMERGENCE. (July 1928).

| Hour | Date 24 No. emerged | 24 Temp. | 25 No. emerged | 25 Temp. | 26 No. emerged | 26 Temp. |
|---|---|---|---|---|---|---|
| 4 p.m. | | 88 | | 90 | 1 | 78 |
| 6 p.m. | | 88 | | 87 | 2 | 72 |
| 8 p.m. | | 86 | 1 | 82 | 6 | 72 |
| 10 p.m. | | 80 | 4 | 75 | 4 | 72 |
| 12 m. | 1 | 74 | 8 | 73 | 3 | 70 |
| 2 a.m. | 6 | 70 | | 70 | | 68 |
| 4 a.m. | 4 | 68 | | 68 | | 66 |
| 6 a.m. | 2 | 68 | | 70 | | 67 |
| 8 a.m. | | 76 | | 82 | | 70 |

The earliest emergence recorded was July 16; the latest Aug. 17, and the peak or point of maximum emergence occurred during the last week of July.

There is very little difference in the time of appearance of the two sexes, altho as a rule the male sex predominates for the first few days after which the females outnumber the males (table XV).

SEX PROPORTIONS AND MATING: Of the 290 individuals tabulated in table XV, 158 or approximately 54 per cent were males and 132 or approximately 46 per cent were females. This indicates that the two sexes occur in about equal numbers.

TABLE XV. DATES OF ADULT EMERGENCE.

| Date | 1927 | | 1928 | | 1929 | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| July 16 | 1 | | 1 | | | |
| 17 | | | | | | |
| 18 | | | 1 | | | |
| 19 | 1 | 1 | | | 1 | |
| 20 | | | 5 | 4 | 1 | |
| 21 | | | 4 | 1 | 3 | |
| 22 | | 1 | 12 | 4 | 3 | 2 |
| 23 | | 1 | 10 | 11 | | 1 |
| 24 | 1 | | 7 | 5 | 1 | 2 |
| 25 | 1 | 1 | 7 | 7 | 1 | 1 |
| 26 | 2 | | 11 | 4 | 6 | 5 |
| 27 | 1 | 2 | 7 | 5 | 5 | 2 |
| 28 | 1 | 2 | | | 1 | 2 |
| 29 | 1 | 2 | | | 3 | 3 |
| 30 | 1 | 1 | 2 | 2 | 3 | 2 |
| 31 | | | | 1 | 4 | 4 |
| Aug. 1 | 1 | 1 | | | 1 | 3 |
| 2 | | | 1 | 2 | | |
| 3 | | | 12 | 4 | 3 | 5 |
| 4 | 1 | | 4 | 4 | 2 | 1 |
| 5 | 1 | 1 | 7 | 9 | 1 | 2 |
| 6 | | | 4 | 4 | | |
| 7 | | | 3 | 2 | 3 | |
| 8 | | | | 1 | 2 | |
| 9 | | | | 2 | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | 3 | | 2 |
| 13 | | | | | 1 | 3 |
| 14 | | | | | | 1 |
| 15 | | | | | | |
| 16 | | | | | 1 | 2 |
| 17 | | | | | 1 | 1 |
| Total | 13 | 13 | 98 | 75 | 47 | 44 |

Mating usually takes place the first night after emergence. Before copulating the female usualy comes to rest on the side of the cage or on a stem of grass, slightly raises the tip of her abdomen and passively awaits the arrival of a male. Upon making his appearance the male flutters excitedly about for a time but finally alights near the female and immediately attempts to clasp with her. The pair remain in coition for from 10 to 110 minutes.

OVIPOSITION: Altho the preoviposition period varies from one to six days, the greatest number of females begin laying the second night following emergence. The time of mating greatly influences the length of the preoviposition period. Unfertilized females usually hold their eggs until just before death, when a portion of them may be deposited. The oviposition period varies from three to seventeen days with an average of six and two-tenths days. The moths do not always lay eggs every day during the oviposition period, but as a rule a moth which has once begun to lay will deposit a few eggs each day until all have been deposited.

The postoviposition period ranges from none to nine days with an average of two and three-tenths days. Five out of forty-one females laid eggs during the day on which death occurred.

Oviposition occurs at night. Shortly after sundown the females begin to deposit their eggs. In our cage experiments oviposition was at its peak between 9 and 11 o' clock, and only a few stragglers laid after midnight.

The female first flutters about among the plants apparently seeking a suitable place to deposit her eggs. Upon alighting on a plant the tip of the abdomen is immediately turned downward and the ovipositor extended to seek about for a crack or crevice in which to oviposit. When a desirable location is found she deposits a mass of from one to one hundred eggs without changing her position. The number of eggs deposited by individual females on particular days and during their whole lives varies greatly (table XVI). In most cases from 50 to 240 eggs are laid on the first night and successively smaller numbers each day thereafter. In cage experiments, where the eggs were removed daily, the total number of eggs deposited by a female varied from 17 to 812 with an average of 396. In another set of experiments where the moths were caged over both living and dead grasses and left undisturbed, the limits of variation remained about the same, but the average was raised to 519. This would indicate that the moths withheld a portion of their eggs when placed under extremely artifical conditions.

The moths oviposit freely on different kinds of grasses and as a rule the eggs are placed well-down under the leaf sheath or in some rolled or folded leaf (fig. 4).

LONGEVITY: Adult males lived from three to nineteen

TABLE 16. EGG LAYING PERIOD AND LIFE ACTIVITY CHART OF TEN FEMALES (1928).

| Record number | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Total Number of Eggs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 77 | E | M | 103 | 146 | 20 | 77 | | D | | | | | 306 |
| 78 | E | | 89 | 101 | 32 | 90 | 112 | | 47 | | | D | 471 |
| 81 | E | M | 215 | 53 | 81 | | | | D | | | | 349 |
| 83 | E | M | 214 | | | | | | D | | | | 214 |
| 86 | E | | 60 | 117 | 166 | | 35 | 45 | D | | | | 423 |
| 87 | E | 34 | 70 | 65 | 52 | 68 | 62 | 45 | 56 | D | | | 452 |
| 76 | E | | | | | | | | | 79 | D | | 79 |
| 90 | E | 65 | 169 | 33 | D | | | | | | | | 267 |
| 91 | E | M | 154 | | | | | D | | | | | 154 |
| 107 | E | | 6 | 130 | | D | | | | | | | 136 |
| Average of those laying | | 49.5 | 120 | 92.1 | 70.2 | 78.3 | 69.7 | 45 | 56 | 79 | | | |
| Average of 10 | | 9.9 | 108 | 64.5 | 35.1 | 23.5 | 20.9 | 9.0 | 5.6 | 79 | | | 284 |

E. emerged. M. mated, D. dead.

days, with an average length of life of eight and five-tenths days. Females lived from five to twenty-one days, with an average of eight and six-tenths days. Since most of the moths emerge during the hottest part of the summer their rate of metabolism is high and their length of life is comparatively short. Moths placed in a cool cellar lived from seven to twenty-nine days. Availability of water was an important factor in determining their length of life. Moths deprived of water invariably died in less than a week. On the other hand it did not appear that food was very essential. Moths supplied with sweetened water lived no longer than those given only distilled water.

GENERAL HABITS: The adult moths are seldom seen in the field even in localities where they are known to be abundant. During the day they remain hidden under leaves and in dense grass where they are not readily observed nor easily disturbed. Shortly after sundown they become somewhat active and begin to flutter among the plants. Their sluggish flights are short and follow an irregular, zigzag course, the moths seldom flying more than a few feet at a time.

According to published records the moths are sometimes taken at lights, but in the opinion of the writer this is an unusual occurrence. Repeated efforts were made to attract the moths to lights, and in practically all cases the results were negative. The lights used varied from a kerosene lantern to a 100 watt Mazda lamp. Both bright and dim automobile head lights also were tried. Only four moths, three males and one female were taken at lights.

The moths were not attracted to sweetened substances. Altho caged moths did drink sweetened water there was no evidence that they preferred it to distilled water.

The moths frequent low moist situations, which are the natural habitats of the food plants of the larvae. To illustrate: The borer seriously damaged corn in two fields which were located on very low ground. Because no slough grass or other wild hosts could be found in the immediate vicinity it was difficult at first to account for the presence of the borer. It was later found, in both cases, that a good stand of heavily infested Spartina occurred on considerably higher ground not more than half a mile away from the field. Apparently the moths had been attracted from their natural host to the environmental conditions existing in the lowlands.

SEASONAL HISTORY

The eggs of Luperina stipata are laid on the stems and leaves of grasses during late July and August but do not hatch until April or May of the following spring. The newly hatched caterpillars make their way into the young grass plants. Several plants may be destroyed during the course of the larval feeding period which usually lasts from 70 to 85 days. Transformation to the pupal stage takes place in an especially constructed cell in the soil, beginning about July 1 and continuing up to about July 20. The adult moths emerge during late July and early August and deposit their eggs on the grasses where they remain over the winter. The seasonal history is illustrated graphically, in fig. 16.

## NATURAL CONTROL

There are several natural enemies of the four-lined borer, two or three of which are of major importance. They are represented by: two Diptera, seven Hymenoptera, four Coleoptera, three Hemiptera, two mammals, one bacterial disease and two fungus diseases. The amount of parasitism in the case of larvae collected from slough grass varied from 8 to 67 per cent, but it should be noted that very few parasites were reared from larvae taken from corn. Two hundred and fifty larvae taken from a corn field did not yield a single parasite, while a lot of 201 larvae taken from slough grass in a near by fence row was 37 per cent parasitized.

PARASITIC INSECTS: Masicera senilis Mg., the most common dipterous parasite, is very active and in many cases it is responsibe for over half of the total parasitism.

In field collections from 12 to 34 per cent of the caterpillars were parasitized by this fly. As a rule only one maggot emerges from a single host, but the emergence of two is fairly common, and in one case a single host larva produced three maggots. Larvae pupated from July 1 to 22 and the flies emerged from July 12 to Aug. 6. This species has been reared from a number of other stalk borers including Macronoctua onusta Grote, Papaipema nebris (Gn.) P. cataphracta Grote and two other undetermined species of Papaipema.

Three specimens of Winthemia quadripustulata (Fab.) were reared. In two cases the parasite maggots emerged from last instar larvae and pupated in the soil, while in the third case the fly emerged direct from a moth pupa, the maggot having pupated within the host. Emergence dates were July 1, 6 and 19, 1929. Altho not an important parasite of Luperina stipata this species is very common in the state and is frequently reared from army-worms and cutworms.

Among the important parasitic Hymenoptera attacking this insect is a large ichneumon fly of the genus Ectopimorpha (fig. 17), which is soon to be described by Mr. R. A. Cushman. The stage of development of the host at the time it is attacked by the parasite is not known. Pupation takes place within the pupa of the host, and the adults emerge 15 to 20 days after the host has pupated.

Two specimens of a closely related species, Amblyteles jucundus Brulle, were also reared from pupae of the borer. This species has also been bred from Macronoctua onusta Grote and Papaipema nebris Gn. and is reported as a parasite of several cutworms.

Meteorus vulgaris (Cress), a medium small gregarious braconid, parasitizes as high as 12 percent of the larvae collected in the field. Adults emerged from July 2 to 21. Adults that emerged July 9 were placed in a vial with three host larvae, on July 11. Oviposition was not observed, but the host larvae were saved and reared. On July 22 and 23, seven, eleven and fourteen larvae of this parasite emerged from the caterpillars and spun their cocoons. Five days later the adults emerged.

Apanteles laeviceps Ashm. and A. militaris Walsh., two common parasites of cutworms, were reared in small numbers.

Lissonota brunnea Cress. one of the larger ichneumon parasites, was found to be a rather common parasite of the borer. The mature larvae emerged from the caterpillar and pupated during late July and issued as adults the following May.

Microplitis gortynae Ril. (fig. 18), a small gregarious parasite, was reared in quite large numbers. It sometimes parasitized as high as 30 per cent of the larvae. From six to twenty-two larvae emerged from a single caterpillar and immediately spun up in reddish brown, ribbed cocoons. The larvae spun their cocoons during the first two weeks of July, and altho the time of pupation was not determined the adults did not emerge until the following May.

PREDATORY INSECTS: Among the predacious insects the ground beetles are of greatest importance. The "fiery hunter" (Calosoma calidum Fab.) (fig. 19) is very active in destroying the caterpillars, and a single beetle may destroy from 50 to 100 or more caterpillars during its life. In cage experiments it was found that nearly full-grown Calosoma larvae and adult beetles are both capable of devouring a full-grown caterpillar every day, and adults have been observed to kill as many as three, eating only a part of each one.

Scarates subterraneus var. substratus Hald. (fig. 20), a large black beetle, was observed to be very common and was one of the most voracious feeders. Like the Calosoma beetles they were able to eat one or more larva each day.

Three species of carabids, Evarthrus colossus Lec., E. sodalis Lec. and Galerita janus Fab., have been observed to be quite consistent feeders upon the borers and other noctuid larvae.

Several other species, including Harpalus caliginosus Fab., H. pleuriticus Kirby, H. pennsylvanicus Dej., Pterostichus permundus Say, and P. lucublandus Say, were found to be commonly associated with the borer in Spartina sod, but the extent of their predatory habits was not determined.

Three species of insects belonging to the order Hemiptera were observed to attack young larvae while they were working above ground. Two adults and one nymph of Podisus maculiventris (Say), two adults of Nabis ferus L. and one undetermined reduviid nymph constitute the total number of observations on hemipterous predators.

MAMMALS: Moles, which occasionally have runways along fence rows and in infested sod, destroy the pupae and probably some larvae. It is difficult to find undestroyed pupae in the vicinity of a mole burrow. In the same way the short-tailed shrew (Blarina brevicauda Say) has been known to destroy many pupae.

DISEASES: One bacterial and two fungus diseases were observed to attack the borer, but during the three years covered by this study they were only occasionally encountered and do not appear to constitute a very important factor in the control of this insect.

Most of the diseased larvae turned quite reddish in color. Later part of them developed a soft white fungus growth over the entire body while the others soon became a soft watery mass. Larvae killed by the third type of disease *Cordyceps* sp. develop prominent white fruiting bodies.

## CONTROL

The four-lined borer is primarily a weed and wild grass insect. It breeds extensively in common slough grass and it is more or less accidentally that corn or other crops are attacked. Apparently the eggs are laid at random upon the lowland grasses, and it is only a matter of chance that the young larva finds a suitable host. If the slough grass and other large stemmed grasses which grow in the fence rows and in low poorly drained fields are destroyed, most of the larvae will perish, and the borer population will be so reduced that an outbreak will be practically impossible.

Burning fence rows and grasslands between November first and April first destroys the eggs, but since most of the parasites spend the winter beneath the surface of the soil they would be uninjured by the fire.

## The Stalk Borer
## Papaipema nebris (Gn.)

The Stalk Borer, a native American insect, was mentioned as a pest in some of the earliest writings on economic entomology. Even prior to its description as a species by Guenee in 1852 we have three records of its doing considerable damage to crops. Under date of July 27, 1823, Thomas Beesley (6) of Cape May, wrote a letter to the editor of the American Farmer in which he described a worm that was eating into the wheat straws. In 1840 Jabez Jenkens (28) of West Whiteland, Pennsylvania, described the larva and its characteristic injury to wheat as follows: "I have not yet seen any published account of a new enemy that has made its appearance in the wheat this year. Many fields in Chester and Delaware Counties, and perhaps elsewhere, have been in some degree injured by it. At mowing time when wheat was beginning to ripen, I walked into an adjoining field, when I observed a considerable number of dead heads, and standing in the worst discovered part, I plucked, without moving, six of them. On examination, a small hole was found in the upper joint of the stalk, and within, between that and the head, a worm about three quarters of an inch in length, of a brown color, striped at both ends, and with a reddish head; it was very active. In some cases the worm had entered the stalk lower, but soon made its exit, boring another hole near the first, leaving such heads only partly injured." In 1848 T. W. Harris (25) described the larvae and recorded its boring in potato vines. Asa Fitch (16) 1857 recorded it as boring in potato stems and noted that he believed it to be an undescribed species of the genus Gortyna. In all of the foregoing records the identity of the pest was unknown but fortunately the descriptions given are sufficiently accurate and complete that there is little doubt but what P. nebris is the species concerned. Harris and Fitch both referred to the borer as common in potato vines and thus left the impression that they were quite familar with it.

Dr. C. V. Riley (37) was first to recognize the borer as Guenee's species and in 1867 he published a brief though partly erroneous, account of its life history and habits; figures of the larva and adult stages, and descriptions of the larva, pupa and adult. During the next fifteen years Riley added many notes, most of which were published in the Missouri Entomological reports, the American Entomologist and various farm papers.

In 1871 Lé Baron (29) reported the destruction of two acres of wheat at Madison, Wisconsin and according to Smith (43) fifteen acres of corn was destroyed at Elmira, Illinois in 1877.

In 1905 Bruner (12) stated that wheat, in the eastern half of Nebraska, was severely damaged by the borer and the same year (1905) Weldon (57) reported that the borer was a serious pest from Maine to Mississippi and West to Minnesota and Iowa.

From 1867 to date hardly a single year has passed that the stalk borer has not been reported as doing more or less damage. From 1902 to 1908 it received annual mention as one of the principal insects of the year in the year book of the Department of Agriculture. Likewise it has received annual mention in the Insect Pest Survey from its inauguration in 1922 to date. These reports indicate that the borer was abnormally abundant in 1904, 1905, 1908, 1923, 1926, 1927, and 1929.

In 1927 (Insect Pest Survey) the stalk borer was listed as one of the ten most destructive insects of the year by three collaborators of the U. S. Bureau of Entomology, Insect Pest Survey.

In 1890 Mr. J. M. Shaffer (42) reported a general infestation of the borer in the vicinity of Keokuk, Iowa.

In 1923 the borer was very abundant in Iowa and several fields of corn were seriously damaged. One twenty-acre field of corn near Marshalltown was completely destroyed. In 1926 and 1927 the borer was unusually destructive in all parts of the State and there were many reports of serious damage. One forty-acre field in Lee County was eighty per cent destroyed. Although there were many reports of injury in 1928 and 1929 the borer was not so abundant as ~~in~~ during the previous two years.

In addition to the foregoing reports, E. A. Smith (43) Lintner (32), J. B. Smith (47), Washburn (49), (50), Bird (9), (10) and Lowry (33) have made valuable contributions to our knowledge of the life history and habits of this insect.

DISTRIBUTION

This species has a wide distribution in the United States. Records show that it has a range extending from the Atlantic coast west to the Rocky Mountains and from southern Canada and from the New England states south to the Gulf of Mexico. It has been recorded as occurring in Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Maine, Vermont, New Hampshire, Massachusetts, Connecticut, New York, Pennsylvania, New Jersey, Maryland, North Carolina, South Carolina, Georgia, Mississippi, Louisiana, Tennessee, Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, Virginia, West Virginia, Nebraska, Iowa, Missouri, Kansas and Arkansas. It has also been reported as occurring on celery in British Columbia (41). However, Mr. Max H. Ruhman of Vernon, B. C. the author of the above reference, has written to me as follows: "There is considerable doubt as to the accuracy of this identification. The determination was made by the late R. C. Treherne from a single larva." With this information at hand and a knowledge of the habits of this insect the writer feels certain that this was a case of incorrect identification, and the range of P. nebris is limited to the area east of the Rocky Mountains, and possibly to the region East of the 100th. Meridian (the limit of many eastern species) for it is worthy of note that practically all reports from Nebraska and the Dakotas specify the eaxtern half of the state,

The writer has collected stalk borers in all sections of the State and has records to show that it is a common pest in every County of Iowa. It seems probable that borers could be found on practically every farm in the State.

HOST PLANTS.

The Stalk Borer is a rather indiscriminate feeder and is known to attack 176 different species of plants, representing 44 families. Of these 129 have been found as hosts of the borer in Iowa and the remaining 47 although not recorded here have been cited in literature. In the early spring the larvae are most abundant in the grasses, but as they develop in size the small grass stems are found to be unsuitable to their needs and about July first they transfer their activity to a larger stemmed plant. During this migration the larvae seem to show little preference in the selection of a host, readily accepting almost any succulent plant with a moderately large stem. For
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will be said concerning this problem of host selection under the heading of Larval Habits.

CLASSIFIED LIST OF THE HOST PLANTS OF *P. NEBRIS* AS RECORDED IN IOWA.

Typhaceae

*Typha latifolia* L., Cat-tail.

Alismaceae

*Alisma plantago-aquatica* L., Water Plaintin.

Graminaceae

*Zea mays* L., Corn.

*Panicum scribnerianum* Nash., Panic grass.

*Setaria glauca* (L.) Beauv., Pigeon grass.

*Setaria viridis* (L.) Beauv., Green foxtail.

*Stipa spartea* Trin., Porcupine grass.

*Muhlenbergia mexicana* (L.) Trin.

*Phleum pratense* L., Timothy.

*Agrostis alba* L., Red top.

*Calamagrostis canadensis* (Michx.) Beauv., Blue joint grass.

*Avena sativa* L., Oat.

*Triticum sativum* Lam., Wheat.

*Spartina michauxiana* Hitchc., Slough grass.

*Phragmites communis* Trin., Reed grass.

*Dactylis glomerata* L., Orchard grass.

*Poa pratensis* L., Kentucky blue grass.

*Bromus inermis* Leyes.

*Bromus arvensis* L.

*Bromus tectorum* L.

*Agropyron smithii* Rydb., Blue joint.

*Agropyron repens* L., Quack grass.

*Hordeum jubatum* L., Squirrel tail grass.

*Elymus canadensis* L., Wild rye.

*Elymus robustus* Scrib., F. J. G. Sm.

Cyperaceae

*Carex vulpinoides* Mich., Sedge.

Commelinaceae

*Tradescantia reflexa* Raf., Spiderwort.

Liliaceae

*Lilium tigrinum* Ker., Tiger lily.

*Lilium* sp.

*Yucca filimentosa* L., Adams needle.

*Asparagus officinalis* L., Asparagus.

Iridicacea

*Iris versicolor* L., Large blue flag.

*Iris* sp.

*Gladiolus* sp.

Salicaceae

*Salix nigra* Marsh., Willow.

*Salix cordata* Muhl., Willow.

*Salix longifolia* Muhl., Willow.

*Salix amygdaloides* Anders., Willow.

*Populus alba* L., Poplar.

*Populus deltoides* Marsh., Poplar.

Urticaceae

*Ulmus fulva* Mich., Elm.

*Ulmus americana* L., Elm.

*Cannabis sativa* L., Hemp.

*Urtica gracilis* Ait., Nettle.

Polyganaceae

*Rumex crispus* L., Curly dock.

*Rumex mexicanus* Meisn., Mexican dock.

*Rumex altissimus* Wood., Pale dock.

*Polygonum lapathifolium* L., Smartweed.

*Polygonum pennsylvanicum* L., Smartweed.

*Polygonum persicaria* L., Smartweed.

*Polygonum convolvulus* L., Black bind weed.

*Fagopyrum esculentum* Moench., Buckwheat.

*Rheum rhaponticum* L., Rhubarb.

Chenopodiaceae

*Chenopodium album* L., Lamb's quarters.

*Spinacia oleracea* L., Spinach.

*Beta vulgaris* L., Beet.

*Beta vulgaris*, Sugar beet.

Amaranthaceae

*Amaranthus retroflexus* L., Green pigweed.

Nyctaginaceae

*Oxybaphus nyctagineus* (Michx.) Sweet., Wild Four O'clock.

Carophyllaceae

Carophyllaceae

*Saponaria officinalis* L., Bouncing Bet.

Ranunculaceae

*Ranunculus* sp., Buttercup.

*Thalictrum dasycarpum* Fisch. & Lall., Meadow rye.

*Anemone canadensis* L., Anemone.

*Delphinium penardi* Huth., Prairie larkspur.

*Peonia* spp., Peony.

Saxifragaceae

*Ribes aureum* Pursh., Missouri currant.

Rosaceae

*Crataegus* spp.

*Potentilla arguta* Pursh., Five-finger.

*Potentilla monspeliensis* L., Five-finger.

*Rubus idaeus* L., Wild raspberry.

*Rosa pratincola* Greene, Prairie Rose.

*Prunus virginiana* L., Choke cherry.

Leguminosae

*Melilotus officinalis* (L.) Lam., Y. Sweet clover.

*Melilotus alba* Desr., W. Sweet clover.

*Medicago sativa* L., Alfalfa.

*Petalostemum purpureum* (Vent.) Rydb., Prairie clover.

*Phaseolus vulgaris* L., Bean.

Anacardiaceae

*Rhus glabra* L., Sumach.

Aceraceae

*Acer negundo* L., Box elder.

Vitaceae

*Vitis vulpina* L., Frost grape.

Malvaceae

*Althaeae rosea*, Hollyhock.

Onagraceae

*Oenothera biennis* L., Evening primrose.

Umbelliferae

*Osmorhiza longistylis* (Farr.) Dc., Sweet Cicely.

*Pastinaca sativa* L., Parsnip.

Primulaceae

*Steironema lanceolatum* (Walt.) Gray.

Apocynaceae

*Apocynum androsaemifolium* L., Dogbane.

Polemoniaceae

*Phlox pilosa* L., Phlox.

Labiatae

*Teucrium canadensis* L., wood sage.

*Agastache nepetoides* (L.) Htze., Giant hyssop.

*Leonurus cardiaca* L., Motherwort.

*Monarda mollis* L., Horse mint.

Solanaceae

*Lycopessicum esculentum* Mill., Tomato.

*Solanum tuberosum* L., Potato.

*Solanum melongena* L., Eggplant.

*Physalis pubescens* L., Ground cherry.

*Physalis lanceolatum* Michx., Ground cherry.

*Nicotiana tobacum* L., Tobacco.

Scrophulariaceae

*Verbascum thapsus* L., Mullein.

*Veroinca virginica* L., Culver's Root.

Plantaginaceae

*Plantago rugelii* Dcne., Plantain.

Caprifoliaceae

*Sambucus canadensis* L., Elder.

Compositae

*Solidago canadensis* L., Golden-rod.

*Solidago rigida* L., Golden-rod.

*Solidago* sp., Golden-rod.

*Aster cordifolius* L., Aster.

*Aster laevis* L., Aster.

*Aster multiflorus* Ait., Aster.

*Aster* sp., Cultivated aster.

*Erigeron canadensis* L., Horse weed.

*Silphium laciniatum* L., Compass plant.

*Iva xanthifolia* Nutt, Marsh elder.

*Ambrosia trifida* L., Great Ragweed.

*Ambrosia artemisiifolia* L., Lesser Ragweed.

*Xanthium commune* Britt., Cocklebur.

*Heliopsis scabra* Dunal., Ox-eye.

*Rudbeckia hirta* L., Black-eyed Susan.

*Brauneria purpurea*, Purple Cane-Flower.

*Lepachys pinnata* (Vent.) T. & G.

Compositae (continued)

*Helianthus annuus* L., Sunflower.

*Helianthus occidentalis* Riddell.

*Helianthus grossesserratus* Martens.

*Helianthus tuberosus* L., Jerusalem artichoke.

*Dahlia* spp., Dahlia.

*Bidens frondosa* L., Beggar-tick.

*Bidens cernua* L., Stick-tight.

*Achillea millefolium* L., Yarrow.

*Cacalia tuberosa* Nutt., Indian plantain.

*Colendula officinalis* L., Marigold.

*Arctium minus* Bernh., Burdock.

*Cirsium iowense* (Pammel) Fernald., Iowa thistle.

ADDITIONAL HOST PLANTS OF *P. NEBRIS* THAT HAVE BEEN MENTIONED IN LITERATURE BUT THAT HAVE NOT BEEN RECORDED AS HOSTS IN IOWA.

Graminaceae

*Secole cereale* L., Rye.

*Hardeum sativum* Jessen., Barley.

Liliaceae

*Lilium superbum* L., Lily.

*Lilium candidum* L., Madona Lily.

Cannaceae

*Canna* sp., Canna.

Piperaceae

*Piper* sp., Pepper.

Polygonaceae

Polygonaceae (continued)

*Rumex britannica* L., Great Water Dock.

Chenopodiaceae

*Chenopodium euptarium* ?.

Carophyllaceae

*Dianthus* sp., Carnation.

Ranunculaceae

*Ranunculus acris* L., Fall buttercup.

*Delphinum* sp., Golden Larkspur.

Cruciferae

*Brassica olacerae* L., var. *Botrytes* Dc., Cauliflower.

Saxifragaceae

*Ribes* sp., Gooseberry.

*Ribes* nigrum L., Black currant.

Rosaceae

*Spiraea* sp., Spiraea.

*Pyrus malus* L., Apple

*Fragaria* sp., Strawberry.

*Rubus* sp., Blackberry.

*Rosa* sp., Rose.

*Prunus persica* L., Peach.

*Prunus domestica* L., Plum.

Leguminosae

*Trifolium pratense* L., Red clover.

*Phasealus multiflorus* Willd., Scarlet Runner Beans.

*Pisum sativum* L., Pea.

Eupharbiaceae

*Ricinus communis* L., Castor Bean.

Aceraceae

*Acer saccharinum* L., Silver maple.

Vitaceae

*Vitis* sp., Grape.

Malvaceae

*Hibiscus* sp., Rose mallow.

*Gassypium herbaceum* L., cotton.

Umbelliferae

*Apium graevolens* L., Celery.

Oleaceae

*Fraxinus* sp., Ash.

Asclepiadaceae

*Asclepias* sp., Milkweed.

Palemoniaceae

*Phlox* sp.

Labiatae

*Salvia* sp., Sage.

*Collinsonia canadensis* L., Stone root.

Bignoniaceae

*Catalpa bignonioides* Walt., Catalpa.

Cucurbitaceae

*Cucumis melo* L., Muskmelon.

Compositae

*Bellis* sp., Daisy.

*Callisterphus chinensis* Ness., China Aster.

*Xanthium strumarium* L., Cocklebur.

*Rudbeckia lacinata* L. var. Golden-glow, Golden-glow.

*Cosmos bipinnatus* Cav., Cosmos.

*Gaillardia* sp.

*Chrysanthemum eucanthemum* L., Marguerite.

*Chrysanthemum* sp.

*Cirsium arvense*, Canada thistle.

*Cirsium* sp., thistle.

## CHARACTER OF INJURY

The nature of the injury inflicted by the borer varies considerably, depending upon the kind and the age of the host, as well as the age of the larvae.

In the early spring the newly hatched larvae usually enter the nearest suitable host plant, and since the grasses are the dominant form of vegetation at this time they are most noticeably affected although a great many seedling weeds are also attacked. The larvae usually gain entrance to the grasses by crawling under a leaf sheath and then boring into the stem, but they may also bore straight in through the leaf sheath or crawl to the top and work down into the heart of the plant. Working within the stem the larvae frequently cut it off entirely leaving the dead head held in place suspended by the leaf sheath. This is especially noticeable in blue grass during the early part of June. In seedling weeds, the young larvae usually work as leaf miners. They work their way to the midrib and down thru the petiole into the main stem but ocoassionally the "mine" may be deserted after which larvae migrate to the main stem or even to a new plant where they burrow into the main stem.

Regardless of the type of plant first attacked the larvae sooner or later kills it or outgrows it i.e. develops to such a size that the diameter of the stem will no longer accomodate the borer. The larvae then migrate, usually under cover of darkness to a new host. It may or may not complete its development in its second host, depending on the size and rate of development of the particular host selected.

Larger stemmed grasses especially those cultivated as cereal crops may frequently be attacked by newly hatched larvae but more often they become infested by migrating caterpillars which burrow in almost anywhere between the base and the head of the plant apparently entering the internodes or nodes without showing very much choice. Once in the stem they burrow upward leaving nothing but the outer wall of the stem so that the heads fail to fill and soon turn yellow, while the rest of the plant remains healthy and green.

Corn is usually attacked when it is from two inches to two feet high. Although a few first instar larvae have been found feeding on the upper epidermis and in the midribs of young leaves this plant is most often attacked as a second host. Injury to the young plants is typically of two forms. In one case the larva burrows into the side and then upwards through the center of the stalk eating away the heart of the plant so that the upper leaves which are cut off from below, soon wilt and die. (Fig. 22) This type of injury, in which the central portion of the plant appears dead while the outer leaves are green and apparently healthy, is commonly known as "dead heart", among the farmers. In the other cases the larva climbs to the top of the plant and then descends into the open heart where it feeds upon the rolled leaves and bud of the plant. As a result of such feeding irregular rows of ragged holes appear in the leaves as they unfold. Both methods of attack frequently result in the destruction of the developing tassel and the deformation of the upper part of the plant. Corn that has successfully passed the so-called "spindle-stage" is not so seriously damaged by the borer. Although it may make larger burrows in the main stalk the plant seems to be able to overcome its effects. Borers have been found in every part of the stalk from the root to the tassel and even in the center of the cobs. (fig. 23). In the peach, willow, elm and other woody plants the borers attack only the terminal portion of the current season's growth.

In the majority of the plants, listed as hosts, the larva bores in nearly anywhere along the main stalk or lateral branches and usually extends its burrow in an upward direction. As a rule the damage is soon noticed due to the wilted or broken down condition of the upper portion of the plant. However, in ragweed, marsh elder, burdock, rhubarb, tobacco and large corn no evidence of wilting was observed, but the presence of the borer was readily detected by the frass and excrement at the base of the plant.

CONFUSION OF INJURY WITH THAT OF OTHER INSECTS.

The injuries produced by several other insects, especially some of the more common boring caterpillars, more or less closely resembles injuries produced by *Papaipema nebris* and thus we find that in some cases the stalk borer is blamed for depredations of others and vice versa.

Several other species of the genus *Papaipema* are found burrowing in stems of plants, but with the exception of *P. purpurifascia* G. & R. working in columbine (*Aquilegia* spp.), *P. furcata* Smith in shoots of ash, *P. humuli*, in hops, *P. cerina* in the Madonna lily (*L. superbum*), and *P. cataphracta* Grote in various plants, most of these borers attack weeds and wild flowers and are seldom seen in the field. As a rule the species of *Papaipema* are remarkably specific in their host selection. *P. cataphracta*, the one exception (in addition to *P. nebris*) is most likely to be confused with the stalkborer because it attacks a large number of cultivated plants and its injury is not at all unlike that of P. nebris. The real test of identity in this case is an examination of the larva itself. In P. nebris the longitudinal stripes are interrupted on the first three abdominal segments whereas in P. cataphracta they are continuous.

Two species of Hadena (H. stipata Morr. and H. fractilinea Grote), are often confused with the stalk borer. The four-lined borer (H. stipata) may be characterized as working entirely under ground. It enters the plant at the crown or just below the surface of the soil and burrows upward into the stalk and in case of the death of the plant it goes down into the soil and then attacks another plant in the same manner. Often all the plants in a hill of corn may be destroyed in this manner without the borer ever appearing above the surface of the groun. The pale yellowish white larvae which are marked with four broad, reddish brown, longitudinal stripes, are easily distinguished from those of P. nebris. The lined corn borers (H. fractilinea) usually ascent the plant and burrow down between the leaves and into the heart of the plant. The larvae are slender; yellowish; reddish brown longitudinally striped, caterpillars, about one inch in length. According to Forbes (17) and Britton (11) the larvae of H. misera and H. semicana closely resemble those of fractilinea, and the injury on corn is quite similar.

The pale western cutworm (Porosagrotis orthozoma Morr.) the larva of which is a dull gray or greenish caterpillar, rather inconspicuously marked with fine greenish or greenish brown longitudinal stripes, frequently does considerable damage to corn. This species almost invariably attacks the plant below the surface of the soil and burrows upward through the center of the stalk. When not actually feeding the larva is usually to be found in the soil, a few inches away from the plant. The color pattern of the larva and its characteristic method of attacking the host should render this species easily distinguishable from the stalk borer.

The spindle worm (Achatodes zea Harris) and the hop-vine borer (Hydroecia immanis Gn.) occasionally injure corn in a manner almost identical to that of P. nebris. As a rule both borers enter near the ground and burrow upward in the stem but at times they are found working down from above. The larva of the former species is a yellowish white caterpillar with the head, thoracic and anal shields, and the pinacula a glossy black, in strong contrast with the uniform body color. The larva of the latter species are dirty-white in color and conspicuously marked with irregular rose-colored blotches, and each body segment, so arranged that they form broken longitudinal stripes.

Wireworms (Melanotus spp.) frequently burrow into the side of the stalk and kill the young corn plant.

The armyworm (Cirphis unipuncta Haw.), the wheat head armyworm (Neleucania albilinea Auct.) the corn ear worm (Heliothis obsoleta Fab.), and the cotton cutworm (Prodema ornithogalli Gn.) when feeding on young corn usually enter the "throat" of the plant and eat large irregular holes in the rolled and unfolding leaves. Upon growing out these leaves present a very ragged appearance.

The sod webworms (Crambus spp.) and the bill bugs (Sphenophorus spp.) are often responsible for the holes in corn leaves but as a rule the holes produced by these insects are quite regular in outline and occur in transverse rows across the blade of the leaf.

In addition to the foregoing insects which attack corn many other lepidopterous larvae have the habit of boring in the stalks and branches of various cultivated plants and weeds and may at times be mistaken for P. nebris. Also there are some sucking insects which injure grasses and cereal crops in such a way so as to leave dead heads supported by plants that appear healthy. And very often this damage is attributed to the activities of young stalk borers.

In most cases where the larva can be found and compared with the descriptions and illustrations presented in this paper it will be an easy matter to decide whether or not the stalk borer is involved.

## SYSTEMATIC HISTORY & SYNONOMY

The stalk borer was first described by Guenee (22) in

1852 under the name of _Gortyna nebris_ and on the same page he described the form _nitela_ as a distinct species _Gortyna nitela_. Almost thirty years later (1878) (43) Riley (39) bred both forms and many intermediate forms from the same material, thus showing they were varieties of the same species. Due to the large amount of confusion that has existed concerning the types and limits of two genera, _Gortyna_ and _Hydroecia_, this species has been frequently changed back and forth from one genus to the other as the types were changed. In 1899 Smith (46) divided the species of _Hydroecia_ into two groups using the name _Hydroecia_ for one and proposing the name _Papaipema_ for the other. These groups were apparently considered by him as sub-genera but later workers have elevated _Papaipema_ to full generic rank, and it now stands a valid genus with _P. cerina_ Grote as its type.

In some regions the variety _nitela_ is more abundant than _nebris_ and so the former came to be considered as the typical form and in most of the literature their correct relationship is reversed. (_Nebris_ is erroneously considered as a variety of _nitela_.) Several writers have recognized that _nebris_ had priority over _nitela_ but for one reason or another they continued to use the latter name. The most recent workers however, have been using the correct name _P. nebris_.

1852 Gortyna nebris Guenee. Spec. Gen. des Lepid. 5, 124.

1852 Gortyna nitela Guenee. Spec. Gen. des Lepid. 5, 124.

1867 Gortyna nitela Riley, C. V, Praire Farmer, Vol. 19, Feb. 23.

1881. Gortyna nitela Riley, Papilio, Vol. 1, p. 106.

1882 Gortyna nitela Lintner, 1st Rept. N. Y. Ent. p. 110.

1893 Hydroecia nitela Smith, Bul. 44, U. S. N. Mus. p. 178.

1898 Hydroecia nitela Bird, Can. Ent. XXX, p. 127.

1899 Papaipema nitela Smith, Trans. Amer. Ent. Soc. Vol. 26, p. 34.

1901 Gortyna nebris Lyman, Canadian Ent. p. 317.

1902 Papaipema nitela Dyar, U. S. Nat'l Mus. Bul. 52, p. 124.

1908 Papaipema nitela Washburn, 12th Rept. State Ent. of Minn. p. 151.

1910 Papaipema nebris Hampson, Cat. Lepid. Phal. Vol. 9, p. 85.

1917 Papaipema nebris Barnes & McDunnough, Cat. Lepid. N. A. p. 69.

1921 Papaipema nebris Bird, Can. Ent. Vol. 53, p. 79.

1927 Papaipema nebris Lowry, N. H. Ag. Exp. Sta. Tech. Bul. 34. p. 8.

## Common names

Many common names have been applied to this species and most of them are based on the larval habit of boring into its host. It is variously referred to as the "heart worm", the "common stalk borer", the "potato stalk borer," the "dahlia borer", etc. However, "The Stalk Borer" has been adopted as the approved name by the American Association of Economic Entomologists. To the farmer the larvae are known as "worms" or "borers".

## Original Descriptions.

### 194. Gortyna Nebris Gn.

Taille des deux sexes; 38 mm. Ailes supér. très-entières, d'un brun de bois clair, avec la ligne coudée seule distincte, d'un blanc-jaunatre plus ou moins éteint. Les trois premières taches blanches, comme dans les especes précédentes, l'intermédiaire souvent jaune. Reiforme composeé d'une tache centrale plus grande, ordinairement jaune, et de cinq ou six autres trés-petites, punctiformes, qui l'entourent. Ailes infér. d'un brun cendré, uni, dans les deux sexes. Thorax et abdomen cendrés. Abdomen long. Base des antennes blanche.

Male plus petit, tout l'espace terminal et subterminal plus clair. Ailes infer. plus pales.

Amerique Septentrionale, Etat des Illinois. Coll. Bdv. et Dbday.

### 195. Gortyna Nitela Gn.

Taille et couleur de la Nebris, dont elle ne dif ere que par l'absence complète des taches blanches, et les palpes un peu plus longs et plus ascendants. Ailes superieures d'un brun-cendré clair, semé d'atomes fins jaunatres. Ligne coudée seule distincte, d'un blanc-jaunatre; derriere elle le fond devient plus clair, puis il reprend son ton general en approchant du bord terminal Aucune tache. On voit seulement, et surtout quand on regarde l'insecte en transparence, deux groupes d'ecailles plus sombres et comme plus serrées, a la place des deux taches ordinaires. Ailes infer. d'un gris-livide uni, avec une lunule cellulaire de part et d'autre.

Etat des Illinois. Coll. Doubleday. Un seul male.

-A-

Plus petite. Des traces d'une subterminale composée de points jaunatres, ombres antèrleuerement de foncé.

Etat de New York. Coll. Doubleday. Un seul male.

DESCRIPTIONS

Egg

Globular to oblate-spheroidal, somewhat flattened, circular in cross section, quadrate in vertical section, pearly white when first laid but soon changing to brownish gray or amber; micropile on slight elevation in center of one flattened pole, surrounded by a rosette of pyriform cells; exochorion sculptured with approximately fifty raised longitudinal ridges and many small cross ridges forming numerous shallow pits, quadrangular in equatorial region and irregular polygonal and trapezoidal near the poles.

Equatorial diameter 0.595 mm. Polar diameter .444mm.

## Larvae

Head light chestnut brown in color with a dark brown or blackish lateral stripe from hind margin forward to include ocelli; trophi dark or blackish; ocelli, six on each side, yellow, approximately equal in size.

Epistoma with normal setae ($E^1$, $E^2$); the distance between $E^2$ on each side more than twice the distance between $E^1$ and $E^2$. Frontal punctures ($F^a$) close together, between and slightly anterior of frontal seta ($F^1$), near lower margin of frons. $Adf^1$ equidistant from $F^1$ and $Adf^2$; $Adf^2$ well behind beginning of LR. Frontal puncture ($Adf^a$) anterior to beginning of LR; equidistant between $Adf^1$ and $Adf^2$; approximately in line with $F^1$ and $Adf^2$. Anterior setae ($A^1$, $A^2$ and $A^3$) forming an obtuse angle; $A^2$ short, about equidistant from $A^1$ and $A^3$; $A^1$ and $A^3$ long. Anterior puncture ($A^a$) equidistant from, and above a line connecting $A^2$ and $A^3$. Posterior setae ($P^1$, $P^2$) long, $P^1$ laterad and slightly posterior of $Adf^2$; $P^2$ posterior and slightly laterad of $P^1$; the distance between $P^1$ and $P^2$ equal to the distance between $P^1$ and $Adf^2$. Posterior punctures two; Pa nearer to $L^1$ than to any other setae; lying between $L^1$ and $Adf^2$; $P^b$ close to and slightly anterior of $P^2$. Late seta ($L^1$) remote from $P^1$ and $A^3$ with which it forms a triangle, $L^1$ $p^1$ being perpendicular to $L^1$ $A^3$. Lateral puncture ($L^a$) remote, postero-ventrad of $L^1$. Ocellar setae ($O^1$, $O^2$, $O^3$) well separated; arranged in the form of an equilateral triangle; $O^1$ directly ventrad of ocellus IV; $O^2$ postero-ventrad of ocellus I; $O^3$ remote, postero-ventrad of ocellus VI. Ocellar puncture ($O^a$) lying between $O^3$ and ocellus VI but nearer to the ocellus than to the setae. Genal seta ($G^1$) remote, postero-ventrad of $O^3$. Genal puncture ($G^a$) antero-dorsad of $G^1$. Subocellar setae ($SO^1$, $SO^2$, $SO^3$) triangularly placed, $SO^2$ very close to ocellus V. Subocellar puncture ($SO^a$) equidistant from and slightly below a line connecting $SO^2$ and $SO^3$. (fig. 28)

Body cylindrical; moderately stout; tapering towards both extremities; without secondary hairs; mostly dirty white or flesh color, with a band of purplish brown around the metathoracic and the first 3 abdominal segments, a subdorsal and a lateral stripe of the same color extending from the band forward to the head and backward to the anal plate, or with only a faint trace of the purple markings. Prothoracic shield broad, partly divided, yellowish to light chestnut brown with a dark lateral stripe. Spiracles oval, black with lighter centers. Anal plate yellowish, fuscous to black along lateral and caudal margins. Crotchets uniordinal, arranged in a mesoseries.

Body setae yellow to amber, moderately long, placed on conspicuous brown tubercles (fig. 25.)

Prothorax: $I^a$, $I^b$, $II^a$, $II^b$, and $II^c$ on the shield; the two former on the cephalic margin, the three latter on the caudal margin; $I^c$ absent, IV and V approximate, cephalad of spiracle; VI bisetose, caudo-ventrad of IV and V: VII represented by a number of setae at the base of the leg. VIII caudo-ventrad of leg.

Mesothorax and metathorax: $I^a$ near dorsomeson, $I^b$, $II^a$ and $II^b$ almost in line and successively ventrad of $I^a$; III caudo-ventrad of $II^b$; IV cephalad of III; V cephalo-ventrad of IV; VI directly ventrad of $II^b$, remote; VII and VIII as on prothorax.

First and second abdominal segments: I near dorso-meson; II caudo-ventral of I; III cephalo-dorsad of spiracle; IV caudad of spiracle; V ventrad of spiracle; VI caudo-ventrad of V; VII cephalo-ventrad of VI, bisetose on first and trisetose on second segments; VIII caudo-ventrad of VII group. IX cephalad of VII group.

Third to sixth abdominal segments; same as first and second except that VII is situated on outer surface of pro-leg.

Seventh abdominal segment: I, II, III, $III^a$, V and VIII as before; IV dropped to a point caudo-ventrad of spiracle; a small tubercle without setae in normal position of IV; VI moved forward, directly ventrad of V, VII unisetose, ventrad and slightly caudad of VI.

Eighth abdominal segment: I and II on prominent rectilinear tubercles; I placed as before; II caudad of I, III cephalo-dorsad of spiracle; $III^a$ cephalad of spiracle; IV caudad of spiracle; V ventrad and slightly cephalad of spiracle; VI caudo-ventrad of V; VII unisetose, ventrad of spiracle; VIII ventrad of VII.

Ninth abdominal segment: II near dorsomeson: I cephalo-ventrad of II: III ventrad and slightly caudad of I; IV ventrad of III; VII caudo-ventrad of IV, near caudal margin of segment; VIII ventrad of VII.

Tenth abdominal segment: Four prominent setae on each half of the plate; five setae at base of each proleg.

Head width, 2.64 - 3.3 mm. Ave. 2.912 mm.

Body length, 26 - 30 mm. Ave. 30 mm.

Pupa

Typical noctuid pupa; (fig. 27) labrum separated from clypeus by distinct suture, labial palpi visible, about one-fifth length of maxillae; mesothoracic wings reaching nearly to ventro-caudal margin of fourth abdominal segment. Maxillae prominent, reaching almost to tip of wings. Prothoracic legs approximately three-fifths as long as maxillae, prothoracic femur exposed; mesothoracic legs slightly longer than antennae, nearly as long as maxillae; methathoracic legs exposed caudad of maxillae extending to tip of wings. Abdominal segments gradually tapering; dorso-cephalic margins of abdominal segments three, four, five, six and seven strongly punctate, pit markings extending around to ventral surface of segments five, six and seven, caudal margins of segments five, six and seven minutely punctate. Spiracles (except eighth abdominal) ellipsoidal, dark brown; eighth abdominal spiracle reduced to slit-like opening. Proleg scars absent, larval setae and setal arrangement on abdominal segments largely retained. Cremaster short, somewhat flattened dorso-ventrally, terminating in two short, slender, divergent, slightly curved spines. Color varying from light to dark brown (according to age). Genital opening of female simple, slit-like, cephalad of eighth abdominal spiracle, cephalic margins of ninth and tenth abdominal segments curved forward towards genital opening; genital opening of male simple, slit-like, on slight elevation caudal of eighth abdominal spiracle, on ventro-caudal margin of ninth abdominal segment.

Length 16-22 mm. Greatest width 5-7 mm.

## Adult

Ground color reddish-brown, the scales more or less tipped with grey or white to produce mouse or fawn grey color. Head smooth on frons, antennae simple (minutely ciliated) pale yellowish brown, lighter near base, set in tuft of white tipped scales; tarsi ringed with white. Fore wings varying shades of brown (olivaceous, reddish, purplish) sprinkled with grey. Base line barely distinguished; antemedial line more or less indistinct, whiti defined with brown on outer margin, irregular and strongly out curved at margin; post medial line distinct, white or yellowish, defined on inner margin and sometimes on outer margin by brown, strongly excurved from costa around reniform, then inwardly oblique to hind margin; post medial space darker than ante medial and terminal spaces; sub terminal line variable in distinctiveness, dentate, yellow or white, defined on inner margin by brown (may be represented by light spots, dashes or wanting; sub terminal space very light along post median line and fading out towards sub-terminal; terminal line poorly defined; cilia and fringe scales brown, pale at base and tips. Ordinarily spots variable in distinctiveness; claviform divided into two small white spots; orbicular small, irregular and white; reniform with central lunule yellow, partly surrounded by small white spots, one to three above and three below. Five small white spots, on costa beginning near reniform; other white spots on outer margin at terminus of principal veins. Hind wing pale grayish brown to smoky above, fawn grey below mixed with brown along costa and terminal margin. Abdomen uniform fawn grey, with dorsal crests on basal segments.

Expanse 25-40 mm.

Var. nitela. Fore wing with the spots (claviform, orbicular, reniform) obscure or represented by indistinct smoky areas.

## SEASONAL HISTORY AND HABITS

### Egg.

The eggs, which are deposited singly or in masses (of from 2 to 100) on the leaves and stems of dead grasses and weeds, are most frequently placed well down between the leaf sheath and the main stem, in rolled and folded leaves or in cracks and crevices of the main stem. (fig. 28). The time, place, and method of deposition is discussed elsewhere in this paper.

The length of the egg stage varies from about seven and one-half to eight and one-half months. Eggs deposited between August fifteenth and October first hatch during the first two weeks of the following May. Although the majority of the eggs normally hatch during the fore part of May extreme variations in soil type and topography as well as variations in the amount of protection offered by shade, leaf mulch, and snow so effect the temperature that hatching is actually prolonged over a period of four or five weeks. In 1927 eggs on a sandy south slope hatched April 30th, whereas eggs on a shaded north slope, where the snow remained until very late in the spring, did not hatch until June first. Similar variations were observed on other years.

The date of hatching, although influenced to some degree by the factors just mentioned, is largely determined by the prevailing temperatures during February, March and

April, especially April. Temperatures below normal for March and April of 1926 and April of 1928 resulted in unusually late hatching of Papaipema eggs. Hatching dates for the five year period (1926-1930) are given in table XVII. It may be noted that the earliest hatching date recorded was April 19 (1930), the latest was June 5 (1928) and that the peak usually occurred between the first and the fifteenth of May.

Table XVII. HATCHING DATES.

| Year | Earliest Date | Peak | Last Date |
|---|---|---|---|
| 1926 | | May 15-20 | |
| 1927 | April 30 | May 5-10 | June 1 |
| 1928 | May 4 | May 10-15 | June 5 |
| 1929 | April 26 | May 1-10 | May 30 |
| 1930 | April 19 | April 25-30 | May 17 |

The date of egg deposition in no way affected the time of hatching. In many cases the first and the last laid eggs hatched on the same day.

## Development.

Certain changes in the external appearance of the egg accompany development. The original pearly white color of the egg lasts but a few hours. In from 24 to 48 hours the egg changes to a uniform brownish-gray or amber and remains practically unchanged until from two to ten days before hatching, depending upon the temperature, when they become very dark in color, in some cases almost black. At this time the young larva may be seen through the chorion of the egg.

Some embryological development takes place during the first few days after egg deposition but within a week development is arrested and the egg remains in this partially developed condition until spring or until after a suitable exposure to some reactivating or accelerating agent such as low temperature. Incubation is slow and gradual during the late winter and early spring months but when the mean daily temperature reaches 45-50° F. development becomes rapid and the eggs hatch in comparatively short time.

Eggs deposited September first and subsequently held under constant temperature and humidity conditions of 27° C. and 75 per cent relative humidity failed to hatch.. Other eggs which were laid on the same day but which were subsequently subjected to temperatures below the minimum effective temperature (5, 0 and -5° C. respectively), for one month or longer developed normally when replaced under conditions favorable to incubation. Still other eggs which were laid on the same day were left out of doors and at two weeks intervals samples were brought in and incubated under favorable conditions. (27° C. and 75 per cent relative humidity). Samples brought in after December first hatched normally and each succeeding lot had a slightly shorter incubation period. A fourth lot of eggs which were held at the high temperature until January fifteenth, then subjected to out of door conditions for one month and returned to favorable conditions hatched normally. Under such conditions of manipulated temperature the egg stage can be reduced from approximately eight months to two months.

Low relative humidities have a slight retarding effect on development but are comparatively unimportant in determining the duration of the egg stage. Prolonged exposure to an atmosphere of less than fifty per cent relative humidity at temperatures above 20°C results in the dehydration and shriveling of the egg but these conditions seldom occur between September and May and consequently few eggs, except infertile eggs are destroyed in this way. Low relative humidities are most harmful to the egg when they occur near the end of the incubation period. At this time they have a marked retarding effect and materially delay hatching. Under such conditions many eggs have been observed in which completely developed larvae had died.

## Larva

**First Appearance:** Newly hatched larvae appear during late April or early May and begin at once to feed upon young grass and weeds. Although hatching normally occurs at night many eggs were observed to hatch during the day. On hot bright days larvae hatching during the day frequently remained hidden until evening, while on cool, cloudy days they went about their business of locating a host plant the same as at night. Except for a few cases in which the larvae ate part of the shells from which they emerged or portions of dead leaves and stems they did not feed until they found fresh green plants.

General Habits: In seedling weeds the newly hatched larvae usually appear as miners in the cotyledons or leaves of the plant, whereas in grasses they usually work directly into the main stem. Upon the death of the initial host the larva migrates to another plant where it burrows into the base of the stalk and thence upward.

Grasses and most small-stemmed plants seldom contain more than one borer per plant but a large branching weed, e. g. a large plant of giant ragweed (<u>Ambrosia trifida</u>), may contain thirty or more borers. In this case the borers are usually in separate burrows, and it is very exceptional to find two or more borers in a single burrow. Whenever the plant in which a borer is working dies or is cut off or when the larva has grown so large that the old stem will not accomodate it, the larvae is forced to migrate to a new plant and usually it is required to make a selection from several available plants. The selection of the new host plant is largely a matter of chance. The larva wanders more or less aimlessly about until it encounters an upright object and then regardless of whether the object is a stick, dead plant or a suitable host plant the borer climbs to the top and examines it thoroughly. In case the object does not prove to be a desirable host plant the borer descends to the ground and starts out as before. Apparently the borers are not aided by sight or scent until they are very close to a plant. Migrating caterpillars have frequently been observed to pass within a few inches of a very desirable corn or ragweed plant and then encounter an upright stick which they would examine minutely before moving on to find a plant.

Newly hatched larvae react positively to light and negatively to the force of gravity the former being the dominant reaction in cases where the two are opposed. Larvae placed in a cylindrical glass jar will collect at the top and on the side nearest the light. If the upper portion of the cylinder is covered with a larger opaque cylinder the larvae will collect on the light side of the crystalline jar and at the lower margin of the opaque cylinder. In older larvae these reactions are not so noticeable and at the time the larvae are preparing for pupation they are practically reversed.

Instars: The number of larval instars varies from seven to sixteen. Most of the borers complete development in from seven to nine instars and individuals having more than twelve instars are quite rare. When the larvae are supplied with an abundance of good succulent food they normally complete development in seven or eight instars and the growth curve is comparatively smooth. When food is of poor quality (hard, dry, sour or moldy) the rate of growth is reduced. Molting continues at regular intervals but the successive instars show little or no increase in size. That this condition also exists in the field is easily shown by collecting material in the field and determining the index growth* for specimens that were in the process of molting.

In this way it was found that the index of growth varied from .64 to .90 (indicating a possible variation of from 6 to about 20 instars) and that these variations were primarily due to variations in the succulence and size of the host plants from which the larvae were taken. Early in the season the larvae made maximum gains in blue grass and a little later in timothy, wild rye and oats, but as these grasses became old and tough larval growth

*According to Dyar's law (13)--"The widths of the head of a larva in its successive stages follows a regular geometric progression," or in other words the quotient obtained by dividing the width of the head capsule of any instar by that of the following instar is a constant. This ratio is referred to in this paper as the index of growth. It should be noted that this is an inverse ratio, the lower the index of growth the greater the actual increase from one instar to the next.

was slowed up and the index of growth rose from .68 to .80. At this time ragweeds were making good growth and the index of growth for larvae feeding on this plant was dropping, showing that the larvae were making more rapid gains than before. Larvae which feed upon blue grass during the first one or two stadia, timothy or other large grasses during the third and fourth stadia, and vigorous growing ragweed during the last few stadia will show the maximum rate of development. The index of growth for these larvae will quite consistently be lower and they will complete development in seven or eight instars. On the other hand larvae which delay their migrations to new and more desirable hosts will show a slower rate of development and the number of instars required to complete development will be greater. From this it may be seen that it is impossible to determine with any degree of accuracy the age or instar of field-collected larvae.

There is a marked tendency toward a sexual difference in the number of molts. In many cases the males complete development with one less molt than do the females.

Duration of Stadia and Length of Larval Life: The len th of each individual stadium depends primarily upon the temperature whereas food and other conditions are of secondary importance. At relatively high temperatures larvae are very active, they feed voraciously and grow rapidly, but when the temperature drops activity and growth are retarded.

When larvae are reared at constant temperature the second stadium is shorter than the first and the stadia after the second became successively longer up to the seventh which is the longest, except in individuals having more than seven molts, in which case, the seventh stadium is shortened and the last stadium becomes the longest. (table XVIII).

TABLE XVIII. DEVELOPMENT OF LARVAE REARED AT 27$^{\circ}$ C.

| No. of molts to complete development | Number of days in each stadium | | | | | | | | | | Total Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | |
| 7 | 4 | 3.6 | 3.7 | 4.5 | 10 | 15 | 28 | | | | 68 |
| 8 | 4 | 3.5 | 3.8 | 4.4 | 5.6 | 7.1 | 13.8 | 28 | | | 71 |
| 9 | 4 | 3.4 | 3.9 | 4.2 | 5.3 | 6.2 | 9.0 | 14.1 | 26 | | 76 |
| 10 | 4 | 3.5 | 3.7 | 4.1 | 5.2 | 6.1 | 7.2 | 8.5 | 13.6 | 24 | 80 |

Larvae reared in the screened laboratory under natural temperature conditions give comparable results except that the first and second stadia may be considerably lengthened by the low spring temperatures and there may be some irregularities in the comparative length of later stadia due to variations in prevailing temperatures. (tables XIX, XX, XXI and XXII).

The larval feeding period is somewhat lengthened as the number of stadia is increased. (tables XXIII, XXIV, XXV, XXVI, and XXVII).

When the length of larval life of males and females

TABLE XIX. DEVELOPMENT OF SEVEN INSTAR LARVAE IN SCREENED INSECTARY

| | Number of days in each stadium | | | | | | |
|---|---|---|---|---|---|---|---|
| 1926 | I | II | III | IV | V | VI | VII |
| Minimum | 8 | 4 | 3 | 4 | 6 | 7 | 18 |
| Maximum | 14 | 7 | 9 | 10 | 12 | 14 | 27 |
| Average | 11.3 | 5.5 | 6.4 | 7.7 | 9.3 | 11.1 | 23.6 |
| Specimens | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 1927 | | | | | | | |
| Minimum | 8 | 3 | 4 | 5 | 5 | 9 | 20 |
| Maximum | 16 | 8 | 9 | 12 | 13 | 16 | 41 |
| Average | 12.4 | 5.8 | 7.5 | 8.3 | 8.8 | 13.3 | 25.3 |
| Specimens | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 1928 | | | | | | | |
| Mimimum | 7 | 3 | 3 | 4 | 5 | 7 | 19 |
| Maximum | 12 | 9 | 9 | 11 | 11 | 21 | 31 |
| Average | 9.7 | 6.0 | 6.7 | 7.4 | 8.5 | 11.4 | 26.5 |
| Specimens | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| 1929 | | | | | | | |
| Minimum | 10 | 4 | 3 | 4 | 4 | 8 | 18 |
| Maximum | 17 | 10 | 9 | 11 | 12 | 14 | 29 |
| Average | 14.3 | 7.2 | 6.1 | 8.8 | 8.4 | 11.0 | 24.5 |
| Specimens | 6 | 6 | 6 | 6 | 6 | 6 | 6 |

TABLE XX. DEVELOPMENT OF EIGHT INSTAR LARVAE IN SCREENED INSECTARY

| | Number of days in each stadium | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1926 | I | II | III | IV | V | VI | VII | VIII |
| Minimum | 8 | 3 | 3 | 4 | 6 | 6 | 6 | 17 |
| Maximum | 14 | 8 | 9 | 10 | 12 | 13 | 15 | 26 |
| Average | 11.1 | 5.4 | 6.2 | 7.7 | 9.0 | 9.7 | 10.2 | 21.2 |
| Specimens | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| 1927 | | | | | | | | |
| Minimum | 9 | 3 | 4 | 5 | 6 | 7 | 7 | 17 |
| Maximum | 16 | 9 | 9 | 11 | 11 | 13 | 13 | 37 |
| Average | 12.2 | 5.7 | 7.1 | 8.4 | 8.8 | 10.4 | 9.9 | 22.9 |
| Specimens | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| 1928 | | | | | | | | |
| Minimum | 7 | 3 | 4 | 5 | 6 | 6 | 7 | 18 |
| Maximum | 13 | 8 | 9 | 9 | 11 | 12 | 13 | 39 |
| Average | 9.8 | 5.6 | 6.5 | 7.3 | 8.7 | 9.3 | 10.0 | 24.5 |
| Specimens | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| 1929 | | | | | | | | |
| Minimum | 11 | 4 | 3 | 4 | 5 | 6 | 6 | 17 |
| Maximum | 16 | 9 | 9 | 11 | 11 | 12 | 13 | 29 |
| Average | 13.9 | 7.4 | 6.3 | 8.3 | 8.6 | 9.1 | 9.8 | 22.7 |
| Specimens | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |

TABLE XXI. DEVELOPMENT OF NINE INSTAR LARVE IN SCREENED INSECTARY

| | Number of days in each stadium | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1926 | I | II | III | IV | V | VI | VII | VIII | IX |
| Minimum | 10 | 3 | 3 | 4 | 6 | 7 | 6 | 7 | 17 |
| Maximum | 15 | 7 | 8 | 9 | 12 | 13 | 13 | 13 | 27 |
| Average | 12 | 5.2 | 6.0 | 7.4 | 9.0 | 9.1 | 9.4 | 10 | 20 |
| Specimens | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 1927 | | | | | | | | | |
| Minimum | 9 | 3 | 4 | 5 | 6 | 5 | 6 | 6 | 17 |
| Maximum | 14 | 8 | 9 | 11 | 11 | 13 | 13 | 14 | 26 |
| Average | 11.9 | 5.5 | 7.1 | 8.2 | 8.2 | 8.9 | 9.1 | 9.8 | 21.1 |
| Specimens | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| 1928 | | | | | | | | | |
| Minimum | 8 | 4 | 3 | 3 | 5 | 6 | 7 | 7 | 18 |
| Maximum | 12 | 8 | 9 | 10 | 12 | 12 | 13 | 17 | 29 |
| Average | 9.6 | 6.1 | 6.2 | 7.3 | 8.0 | 8.7 | 9.3 | 10.2 | 22.5 |
| Specimens | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 1929 | | | | | | | | | |
| Minimum | 10 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 18 |
| Maximum | 16 | 9 | 8 | 10 | 12 | 16 | 13 | 14 | 36 |
| Average | 13.8 | 7.3 | 6.4 | 7.1 | 8.2 | 8.5 | 9.0 | 9.5 | 21.3 |
| Specimens | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |

TABLE XXII. DEVELOPMENT OF TEN INSTAR LARVAE IN SCREENED INSECTARY

| | Number of days in each stadium | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1926 | I | II | III | IV | V | VI | VII | VIII | IX | X |
| Minimum | 9 | 3 | 3 | 4 | 5 | 5 | 6 | 7 | 6 | 16 |
| Maximum | 14 | 7 | 8 | 9 | 12 | 12 | 13 | 15 | 16 | 27 |
| Average | 11.2 | 5.4 | 6.2 | 7.6 | 8.4 | 8.5 | 9.0 | 9.6 | 9.9 | 18.5 |
| Specimens | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 1927 | | | | | | | | | | |
| Minimum | 9 | 3 | 4 | 4 | 5 | 6 | 5 | 6 | 6 | 17 |
| Maximum | 16 | 8 | 9 | 11 | 12 | 11 | 13 | 13 | 14 | 31 |
| Average | 12.5 | 5.5 | 7.4 | 8.3 | 8.0 | 8.4 | 8.2 | 9.3 | 9.8 | 20 |
| Specimens | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 1928 | | | | | | | | | | |
| Minimum | 8 | 4 | 3 | 4 | 5 | 5 | 6 | 6 | 7 | 17 |
| Maximum | 13 | 8 | 9 | 9 | 11 | 12 | 13 | 13 | 15 | 29 |
| Average | 9.7 | 5.9 | 6.6 | 7.0 | 7.9 | 8.4 | 8.5 | 8.9 | 10 | 21.4 |
| Specimens | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| 1929 | | | | | | | | | | |
| Minimum | 9 | 4 | 3 | 4 | 5 | 5 | 5 | 6 | 7 | 16 |
| Maximum | 16 | 9 | 9 | 10 | 10 | 11 | 11 | 13 | 13 | 34 |
| Average | 14.3 | 7.0 | 6.1 | 8.2 | 7.9 | 8.4 | 8.4 | 9.0 | 9.3 | 20.1 |
| Specimens | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |

TABLE XXIII. DEVELOPMENT OF ALL SEVEN INSTAR LARVAE.

| Average | I | II | III | IV | V | VI | VII | Total |
|---|---|---|---|---|---|---|---|---|
| 1926 | 11.3 | 5.5 | 6.4 | 7.7 | 9.3 | 11.1 | 23.6 | 75 |
| 1927 | 12.4 | 5.8 | 7.5 | 8.3 | 8.8 | 13.3 | 25.3 | 81 |
| 1928 | 9.7 | 6.0 | 6.7 | 7.4 | 8.5 | 11.4 | 26.5 | 76 |
| 1929 | 14.3 | 7.2 | 6.1 | 8.8 | 8.4 | 11.0 | 24.5 | 80 |
| Average | 11.9 | 6.1 | 6.67 | 8.05 | 8.75 | 11.7 | 24.97 | 78 |

TABLE XXIV. DEVELOPMENT OF ALL EIGHT INSTAR LARVAE

| Average | I | II | III | IV | V | VI | VII | VIII | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1926 | 11.1 | 5.4 | 6.2 | 7.7 | 9.0 | 9.7 | 10.2 | 21.2 | 80 |
| 1927 | 12.2 | 5.7 | 7.1 | 8.4 | 8.8 | 10.4 | 9.9 | 22.9 | 85 |
| 1928 | 9.8 | 5.6 | 6.5 | 7.3 | 8.7 | 9.3 | 10.0 | 24.5 | 82 |
| 1929 | 13.9 | 7.4 | 6.3 | 8.3 | 8.6 | 9.1 | 9.8 | 22.7 | 86 |
| Average | 11.7 | 6.02 | 6.52 | 7.9 | 8.77 | 9.6 | 9.97 | 22.8 | 83 |

TABLE XXV. DEVELOPMENT OF ALL NINE INSTAR LARVAE.

| Average | I | II | III | IV | V | VI | VII | VIII | IX | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1926 | 12 | 5.2 | 6.0 | 7.4 | 9.0 | 9.1 | 9.4 | 10 | 20 | 88 |
| 1927 | 11.9 | 5.5 | 7.1 | 8.2 | 8.2 | 8.9 | 9.1 | 9.8 | 21.1 | 89 |
| 1928 | 9.6 | 6.1 | 6.2 | 7.3 | 8.0 | 8.7 | 9.3 | 10.2 | 22.5 | 88 |
| 1929 | 13.8 | 7.3 | 6.4 | 7.1 | 8.2 | 8.5 | 9.0 | 9.5 | 21.3 | 91 |
| Average | 11.8 | 6.0 | 6.4 | 7.5 | 8.35 | 8.8 | 9.2 | 9.9 | 21.2 | 89 |

TABLE XXVI. TOTAL DEVELOPMENT OF ALL TEN INSTAR LARVAE.

| Average | I | II | III | IV | V | VI | VII | VIII | IX | X | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1926 | 11.2 | 5.4 | 6.2 | 7.6 | 8.4 | 8.5 | 9.0 | 9.6 | 9.9 | 18.5 | 94 |
| 1927 | 12.5 | 5.5 | 7.4 | 8.3 | 8.0 | 8.4 | 8.2 | 9.3 | 9.8 | 20 | 97 |
| 1928 | 9.7 | 5.9 | 6.6 | 7.0 | 7.9 | 8.4 | 8.5 | 8.9 | 10 | 21.4 | 94 |
| 1929 | 14.3 | 7.0 | 6.1 | 8.2 | 7.9 | 8.4 | 8.4 | 9.0 | 9.3 | 20.1 | 99 |
| Average | 11.9 | 5.95 | 6.57 | 7.77 | 8.05 | 8.42 | 8.52 | 9.2 | 9.75 | 20 | 96 |

TABLE XXVII. DEVELOPMENT OF ALL LARVAE REARED IN SCREENED LABORATORY.

| No. of molts to complete development | Number of days in each stadium | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | XIII | XIV | XV |
| 7 | 11.9 | 6.1 | 6.7 | 8.0 | 8.7 | 11.7 | 25 | | | | | | | | |
| 8 | 11.7 | 6.0 | 6.5 | 7.9 | 8.8 | 9.6 | 10 | 23 | | | | | | | |
| 9 | 11.8 | 6.0 | 6.4 | 7.5 | 8.4 | 8.8 | 9.2 | 9.9 | 21 | | | | | | |
| 10 | 11.9 | 5.9 | 6.5 | 7.8 | 8.1 | 8.4 | 8.5 | 9.2 | 9.8 | 20 | | | | | |
| 11 | 11.6 | 6.0 | 6.6 | 7.5 | 7.9 | 8.0 | 8.2 | 7.9 | 8.9 | 9.9 | 18 | | | | |
| 12 | 11.8 | 6.1 | 6.4 | 7.7 | 8.2 | 8.1 | 8.4 | 8.0 | 7.9 | 8.7 | 9.3 | 19 | | | |
| 13 | 11.7 | 5.8 | 6.6 | 7.6 | 8.1 | 7.9 | 8.1 | 7.9 | 8.4 | 8.6 | 8.9 | 8.9 | 21 | | |
| 14 | 11.9 | 6.0 | 6.4 | 7.4 | 7.8 | 8.2 | 7.9 | 8.3 | 7.9 | 8.5 | 8.2 | 9.1 | 9.4 | 18 | |

having the same number of instars are compared the males will be found to have the longer larval period. When total length of life for all males and all females is considered the females have the longer period due to the fact that they very frequently have an increased number of molts.

Preparation for Pupation: When a larva becomes full grown it usually deserts the plant and forms a small oval cell just below the surface of the soil. In a few instances especially, when the borer is feeding in corn, burdock or very large ragweed plants, pupation occurs in the larval feeding burrow. In such cases the larva drops to the bottom of the burrow where it prepares an oval cell. The old burrow is closed off with a partition of silk and frass and a new opening is prepared. In preparing this opening the larva leaves only the epidermis of the stem intact. When the pupal chamber has been prepared the larva passes into the prepupal stage. After spending from one to six days in this condition the insect sheds its last larval skin and the pupa is revealed.

## PUPA

Immediately after transformation the pupa is creamy white in color, except in many cases the cephalic region, head, thorax and appendages have a distinct greenish tint. In from one to three hours the abdominal segments and the dorsum of the thorax change to yellow or reddish yellow and a few hours later the entire pupa assumes the normal reddish brown color; then, for the next two or three days it retains a bright lustre.

## Time of Pupation.

Pupation normally begins late in July and continues until the last week of August. The earliest date of pupation was July 17(1927) and the latest August 29 (1928); however, the time of pupation is fairly constant from year to year and during the three year period (1927-1929) the maximum variation from the above dates was 3 days. Table XXVIII.

There is a slight tendency for the males to pupate earlier than the females. This is indicated by the earlier arrival at the fifty per cent point in the case of the males (indicated by asterisk in table XXVIII).

## Duration of the Pupal Stage.

The duration of the pupal stage of 2083 pupae reared under normal conditions in the screened insectary varied from 16 to 40 days, with an average of about 25 days. Table XXIX.

The length of the pupal stage is greatly influenced by the prevailing temperatures (table XXX). In 1926 the mean temperatures remained fairly uniform, and there was little variation in the length of the pupal stage (18-25 days). In 1927 the prevailing temperatures during August were moderately low and the pupal period varied from 20 to 30 days but during the first two weeks of September the temperatures were above normal and the pupal period was short (16-21 days). In 1928 and again in 1929 there was a gradual fall in temperature from August first to October first, and the length of the pupal stage increased from 20 days in August to 40 days late in September.

The relative humidity and the amount of moisture present in the soil did not seem to influence, at least to any marked extent, the length of the pupal stage. One lot of pupae was divided and placed in two jars of sand, one of which was kept wet and the other fairly dry. Moths appeared in both cages at the same time, but many of those in the dry sand were abnormal and deformed.

As a rule the pupal stage of the males was from one to three days longer than that of the females. (Tables XXX and XXXI.

There appears to be an inverse relationship between the length of the larval stage, especially the last instar, and the length of the pupal stage.

Very often the pupae developing from late maturing larvae had a pupal stage from one to three days shorter than pupae developing from early maturing larvae. The pupal records for 1926 (table XXX) give further evidence of this inverse relationship. It may be noted that although the temperature remained fairly constant throughout the season the length of the pupal stage became shorter as the season progressed (as the length of larval life became longer).

In addition to the variations due to temperature, sex, and length of larval life there is a large degree of variation in the length of the pupal stage, which is as yet unexplainable. In most instances individuals which pupated the same day and which were kept under similar conditions (often in the same container) showed variations of from three to eight days in the time of emergence. Of the 30 individuals pupating August 11, 1929; 1 emerged the 23rd. day, 3 the 24th., 6 the 25th., 7 the 26th., 6 the 27th., 3 the 28th., 3 the 29th., and 1 the 30th., day after pupation. The females showed approximately the same degree of variation. Similar variations were observed in pupae kept under constant conditions of temperature and relative humidity.

TABLE XXVIII. DATES OF PUPATION

| Dates | 1926 Male | 1926 Female | 1927 Male | 1927 Female | 1928 Male | 1928 Female | 1929 Male | 1929 Female |
|---|---|---|---|---|---|---|---|---|
| July 17 | | | 1 | 2 | | | | |
| " 18 | | | 1 | 2 | | | | 2 |
| " 19 | | | 3 | 2 | | | 1 | |
| " 20 | | | 4 | 1 | 1 | | 1 | |
| " 21 | 1 | 1 | | 2 | 2 | 1 | | |
| " 22 | 1 | | 4 | 2 | 2 | 1 | 13 | 8 |
| " 23 | | | | | 7 | 2 | 4 | 3 |
| " 24 | 1 | | 2 | | 3 | | 8 | 2 |
| " 25 | | | 3 | 4 | 4 | 2 | 6 | 6 |
| " 26 | | | 2 | | 6 | 3 | 7 | 5 |
| " 27 | 1 | | 5 | 2 | 9 | 2 | 5 | 9 |
| " 28 | | 1 | 3 | 2 | 7 | 1 | 16 | 6 |
| " 29 | 4 | 2 | 3 | 2 | 4 | 1 | 12 | 10 |
| " 30 | *4 | 6 | 2 | 4 | 4 | 1 | 15 | 12 |
| " 31 | | 4 | 2 | 3 | 2 | | 12 | 9 |
| August 1 | 1 | * 1 | | 3 | 2 | 2 | 16 | 14 |
| " 2 | | 1 | 4 | 2 | 3 | 1 | 13 | 9 |
| " 3 | | 2 | 3 | 2 | 2 | | 21 | 21 |
| " 4 | 3 | 1 | 8 | 8 | 2 | 6 | 9 | 11 |
| " 5 | 1 | 1 | 14 | 7 | 4 | 1 | 11 | 12 |
| " 6 | | 1 | 6 | 7 | 6 | | 8 | 11 |
| " 7 | | | *4 | 5 | 3 | 6 | 7 | 24 |
| " 8 | | | 16 | 10 | 6 | 10 | 18 | 21 |
| " 9 | 1 | 1 | 1 | 2 | 6 | 15 | *15 | 29 |
| " 10 | 1 | | 1 | 1 | 8 | 11 | 20 | 46 |
| " 11 | 1 | 2 | 5 | 4 | 11 | 23 | 30 | 65 |
| " 12 | 1 | | 4 | 6 | 7 | 11 | 18 | *32 |
| " 13 | | 1 | 9 | 9 | *8 | 29 | 22 | 36 |
| " 14 | 1 | 1 | 6 | *8 | 20 | 22 | 14 | 27 |
| " 15 | | | 5 | 13 | 15 | 50 | 14 | 24 |
| " 16 | | 3 | 2 | 5 | 36 | *85 | 8 | 23 |
| " 17 | | | 2 | 3 | 14 | 40 | 11 | 29 |
| " 18 | | | 5 | 14 | 3 | 24 | 20 | 37 |
| " 19 | | | 3 | 8 | 9 | 38 | 17 | 30 |
| " 20 | | | 1 | 8 | 3 | 10 | 11 | 30 |
| " 21 | | | 3 | 7 | 5 | 19 | 12 | 14 |
| " 22 | | | 5 | 4 | 2 | 7 | 2 | 22 |
| " 23 | | | 5 | 7 | 6 | 11 | 4 | 12 |
| " 24 | | | 2 | 2 | 1 | 1 | 3 | 10 |
| " 25 | | | | 5 | | 1 | 2 | 8 |
| " 26 | | | 1 | 6 | 1 | 1 | 2 | 5 |
| " 27 | | | | 4 | | 9 | | 3 |
| " 28 | | | | 2 | 1 | 2 | 2 | 1 |
| " 29 | | | | | | 1 | | |
| TOTAL | 22 | 30 | 153 | 190 | 235 | 450 | 429 | 678 |

TABLE XXIX. DURATION OF THE PUPAL STAGE.

| | 1926 | | 1927 | | 1928 | | 1929 | |
|---|---|---|---|---|---|---|---|---|
| Days | Male | Female | Male | Female | Male | Female | Male | Female |
| 16 | | | 1 | 3 | | | | |
| 17 | | | 2 | 8 | | | | |
| 18 | | 1 | | 7 | | | | |
| 19 | | 3 | 3 | 16 | | | | 1 |
| 20 | 2 | 6 | 4 | 15 | 1 | 4 | | 3 |
| 21 | 3 | 10 | 9 | 30 | 5 | 9 | 1 | 9 |
| 22 | 5 | 4 | 18 | 25 | 8 | 9 | 10 | 46 |
| 23 | 4 | 3 | 16 | 37 | 11 | 6 | 18 | 108 |
| 24 | 4 | | 30 | 38 | 4 | 17 | 41 | 148 |
| 25 | 2 | | 22 | 21 | 2 | 20 | 63 | 105 |
| 26 | | | 27 | 17 | 7 | 63 | 66 | 72 |
| 27 | | | 21 | 2 | 11 | 127 | 62 | 41 |
| 28 | | | 12 | 1 | 22 | 94 | 47 | 36 |
| 29 | | | 3 | | 29 | 43 | 36 | 19 |
| 30 | | | 2 | | 35 | 18 | 15 | 14 |
| 31 | | | 1 | | 19 | 9 | 9 | 3 |
| 32 | | | | | 15 | 3 | 6 | 4 |
| 33 | | | | | 7 | 3 | 4 | 3 |
| 34 | | | | | 1 | | 5 | 3 |
| 35 | | | | | 2 | 2 | 3 | 3 |
| 36 | | | | | 4 | 5 | 2 | 1 |
| 37 | | | | | 1 | 2 | 2 | |
| 38 | | | | | 2 | 4 | 2 | |
| 39 | | | | | 2 | 3 | 2 | |
| 40 | | | | | 1 | | 1 | |
| TOTAL | 20 | 27 | 171 | 221 | 189 | 441 | 395 | 619 |

TABLE XXX. EFFECT OF TEMPERATURE UPON THE DURATION OF THE PUPAL STAGE

| Date Pupated | Date emerged | Average time Male | Average time Female | Mean Temperature |
|---|---|---|---|---|
| 1926 | | | | |
| July 21 | August 13-15 | 25 | 23 | 74 |
| July 27 | August 17-21 | 25 | 22 | 73.9 |
| July 30 | August 20-23 | 23 | 21 | 73.9 |
| August 4 | August 25-27 | 23 | 21 | 73.5 |
| August 9 | August 29-31 | 22 | 20 | 74.3 |
| August 16 | September 4-6 | 20 | 19 | 74 |
| 1927 | | | | |
| July 18-19 | August 8-12 | 24 | 21 | 72 |
| July 27-29 | August 23-28 | 28 | 24 | 69 |
| August 8 | September 5 | 28 | 25 | 69 |
| August 14 | September 8 | 27 | 24 | 70 |
| August 23 | September 12 | 21 | 20 | 74 |
| August 25-27 | September 12-16 | 20 | 18 | 76 |
| 1928 | | | | |
| July 27 | August 17-18 | 22 | 21 | 75 |
| August 4 | August 28-30 | 26 | 24 | 73.5 |
| August 5-11 | September 2-10 | 29 | 26 | 70 |
| August 15-16 | September 11-15 | 30 | 28 | 69 |
| August 22-23 | September 21-28 | 33 | 30 | 65 |
| August 24-28 | September 28 October 5 | 40 | 37 | 62 |
| 1929 | | | | |
| July 22-23 | August 13-16 | 24 | 22 | 74 |
| July 25 | August 18-21 | 25 | 23 | 73 |
| July 31 | August 24-26 | 26 | 24 | 72 |
| August 13-15 | September 9-11 | 28 | 25 | 70 |
| August 19-20 | September 15-17 | 29 | 27 | 67 |
| August 22 | September 20-22 | 32 | 30 | 65 |

TABLE XXXI. EFFECT OF SEX AND COLOR FORM ON DURATION OF PUPAL STAGE

| | Male | | | | Female | | | |
|---|---|---|---|---|---|---|---|---|
| Year | nitela | nebris | Total | No. | Nitela | nebris | Total | No. |
| 1926 | | | 22.56 | 20 | | | 20.81 | 27 |
| 1927 | 24.31 | 24.72 | 24.53 | 171 | 22.03 | 22.03 | 22.28 | 221 |
| 1928 | 28.96 | 21.21 | 29.00 | 189 | 27.55 | 26.99 | 27.41 | 441 |
| 1929 | 27.15 | 26.90 | 27.04 | 395 | 25.05 | 24.90 | 24.96 | 619 |

## ADULT

### Emergence

Under normal conditions the pupa, while remaining in its earthen cell or at the base of its burrow in the stalk, splits the pupa case along the dorso-median line of the thorax and the moth makes its escape. The newly emerged adult, with unexpanded wings, works its way thorugh the thin ceiling of its earthen cell and upon reaching the surface of the cell crawls upon some upright object where it stops to expand its wings. The expanding and drying of the wings requires from 30 to 40 minutes after which time they are dropped into their normal position and the moth is ready for its initial flight. If disturbed before the wings are fully indurated the moths run or flutter out of danger after which they come to rest and then elevate the wings to complete the drying process. The time required to complete the whole operation of emergence from splitting of the pupal case to the folding of the wings varies from forty-five to eighty-five minutes.

No observations have been made on the actual time of emergence in the field, but in out-of-door cages most of the moths emerged during the night. In the screened laboratory where the pupae were kept on a layer of moist sand in glass containers, the moths emerged at quite definite hours. Emergence usually began between 5:00 and 7:00 P. M., rose to an abrupt peak between 8:30 and 9:00 and then gradually dropped off until the last few emerged just before daylight. Emergence at night appears to be photo-negative reaction. When pupae were placed in a brightly lighted room during the night and transferred to a dark room during the day the moths emerged between 8:00 and 11:00 A. M. A few moths emerging from pupae that were kept in continual darkness emerged at all hours of the day.

The emergence period lasts for about two months, beginning early in August and continuing up to the first week in October. (Table XXXII). The earliest record was August 6, (1927), the latest October 5, (1928), and the peak or point of maximum emergence usually occurred during the first two weeks of September.

There is no marked difference in the time of appearance of the two sexes. As a rule, however, the male sex predominates for the first few days after which the females out number the males. (Table XXXII).

### Proportion of Sexes and Mating

Of the 2,335 individuals that have been reared during the four years covered by these experiments, 1,440 individuals or slightly less than 62 per cent were females, while 895 individuals or a little less than 38 per cent were males. The percentage of females for each of the four seasons was 57, 56, 63 and 64 respectively. In the field the proportion of sexes may be more nearly equal. Many individuals from which pupation and emergence records were obtained were collected as full grown larvae and it is entirely possible that many males had pupated in the field and that the field collections were therefore unjustly weighted in favor of a larger female population.

Mating usually takes place between 8:00 P. M. and 2:00 A. M. on the first night after emergence but when one or two day old males were available mating frequently occurs within a few hours after the emergence of the female moth.

The female moths indicate their readiness for copulation by raising and projecting the tip of her abdomen. (Apparently an attractive odor is emitted). Soon one or more males approach the female against the wind and after

TABLE XXXII. DATES OF ADULT EMERGENCE.

| Dates | 1926 Male | 1926 Female | 1927 Male | 1927 Female | 1928 Male | 1928 Female | 1929 Male | 1929 Female |
|---|---|---|---|---|---|---|---|---|
| Aug. 6 | | | 1 | 1 | | | | |
| " 7 | | | | 1 | | | 1 | |
| " 8 | | | | 3 | | | | |
| " 9 | | | | | | | | |
| " 10 | | | 2 | | | | | |
| " 11 | | | 2 | 1 | | | 2 | 2 |
| " 12 | | | 4 | 1 | | | 1 | |
| " 13 | | 1 | 1 | 1 | | | 6 | 3 |
| " 14 | | | 2 | 2 | | | 3 | 4 |
| " 15 | | | 6 | 2 | | | | |
| " 16 | 1 | | | 1 | | 1 | 7 | 4 |
| " 17 | | | | | 1 | 3 | 2 | 4 |
| " 18 | | | | 2 | 7 | 3 | 1 | 5 |
| " 19 | | 3 | 1 | 1 | 7 | 2 | 4 | 3 |
| " 20 | 2 | 6 | 2 | 1 | 9 | 1 | 1 | 2 |
| " 21 | 2 | *4 | 2 | 3 | 3 | | 4 | 6 |
| " 22 | 4 | 3 | 2 | 4 | 2 | | 9 | 7 |
| " 23 | *2 | 2 | 5 | 2 | 1 | 1 | 11 | 14 |
| " 24 | | | | 2 | 5 | | 15 | 13 |
| " 25 | | 2 | 1 | 2 | 3 | | 20 | 19 |
| " 26 | 1 | | 3 | 5 | 2 | 1 | 15 | 18 |
| " 27 | 3 | | 2 | 1 | 2 | | 12 | 11 |
| " 28 | | | 2 | 3 | 4 | 5 | 10 | 8 |
| " 29 | | 1 | 5 | 9 | 2 | 1 | 12 | 23 |
| " 30 | 1 | 1 | 11 | 6 | 3 | 6 | 17 | 21 |
| " 31 | 1 | 1 | 9 | 8 | 3 | 3 | 11 | 21 |
| Sept. 1 | | 1 | 15 | 11 | 5 | 4 | 12 | 33 |
| " 2 | 2 | | 6 | 8 | 8 | 23 | 17 | 43 |
| " 3 | 1 | | *7 | 3 | 4 | 5 | *14 | 28 |
| " 4 | | 1 | 7 | 12 | 7 | 2 | 19 | 32 |
| " 5 | | | 11 | 8 | 9 | 10 | 19 | *35 |
| " 6 | | 2 | 2 | 6 | 7 | 12 | 14 | 31 |
| " 7 | | | 10 | *19 | 7 | 19 | 17 | 32 |
| " 8 | | | 10 | 12 | 13 | 17 | 17 | 25 |
| " 9 | | | 9 | 10 | 9 | 26 | 14 | 24 |
| " 10 | | | 7 | 13 | *25 | 35 | 19 | 30 |
| " 11 | | | 13 | 23 | 10 | 52 | 14 | 26 |
| " 12 | | | 9 | 15 | 17 | *52 | 15 | 17 |
| " 13 | | | 8 | 7 | 15 | 46 | 10 | 15 |
| " 14 | | | 1 | 3 | 23 | 49 | 6 | 8 |
| " 15 | | | 1 | 4 | 17 | 31 | 5 | 11 |
| " 16 | | | | 4 | 15 | 34 | 7 | 24 |
| " 17 | | | | 1 | 4 | 5 | 4 | 18 |
| " 18 | | | | | 5 | 1 | 8 | 13 |

TABLE XXXII.(continued) DATES OF ADULT EMERGENCE

| Dates | 1926 Male | 1926 Female | 1927 Male | 1927 Female | 1928 Male | 1928 Female | 1929 Male | 1929 Female |
|---|---|---|---|---|---|---|---|---|
| Sept. 19 | | | | | 4 | 4 | 3 | 22 |
| " 20 | | | | | 6 | 9 | 4 | 9 |
| " 21 | | | | | 9 | 13 | 4 | 8 |
| " 22 | | | | | 2 | 5 | 1 | *4 |
| " 23 | | | | | 1 | 2 | 1 | 2 |
| " 24 | | | | | 1 | 1 | | 2 |
| " 25 | | | | | 1 | | 1 | 3 |
| " 26 | | | | | | | 1 | 2 |
| " 27 | | | | | 1 | | 1 | 2 |
| " 28 | | | | | | 3 | 1 | 2 |
| " 29 | | | | | 1 | | 1 | 1 |
| " 30 | | | | | | | 1 | 1 |
| Oct. 1 | | | | | 4 | 8 | | 1 |
| " 2 | | | | | 1 | | | |
| " 3 | | | | | | 3 | | |
| " 4 | | | | | 1 | 1 | | |
| " 5 | | | | | 1 | 1 | | |
| TOTAL | 20 | 27 | 179 | 221 | 282 | 500 | 414 | 692 |

*Fifty per cent point.

TABLE XXXIII. ABUNDANCE OF VAR. NEBRIS AND VAR. NITELA COMPARED

| Year | Male nitela | Male nebris | Male % of nitela | Female nitela | Female nebris | Female % of nitela |
|---|---|---|---|---|---|---|
| 1927 | 108 | 43 | 71 | 146 | 58 | 71.6 |
| 1928 | 125 | 57 | 68.7 | 319 | 112 | 74.0 |
| 1929 | 236 | 69 | 77.4 | 335 | 112 | 74.9 |
| TOTAL | 469 | 169 | 73.5 | 800 | 282 | 73.8 |

hovering about her momentarily alights beside her or strikes at the elevated caudal tip of her abdomen while in flight. As soon as the male succeeds in clasping he reverses his position so that the two moths face in opposite directions. The moths usually remain in coition for 30 to 75 minutes, the average time being about 45 minutes.

## Polygamy

There is considerable evidence of polygyny and polyandry among the moths. Many males have mated with two or more females. Twenty-four out of twenty-five males made second matings, 9 out of 10 made third matings and 5 out of 5 made fourth matings. No attempt was made to secure more than four matings from an individual. In a few cases fertile females that had laid some eggs were observed to mate a second time.

## Time, Manner and place of Oviposition.

According to Smith (47), Wm. Beutenmuller was the first person to describe the egg and to observe the time and place of deposition. Previous to this, time (1905) it was quite generally believed and not infrequently stated that the winter was passed in the adult stage and that the eggs were deposited singly upon the young host plants.

Egg deposition begins the first or second night following mating (usually the second or third night after emergence). Practically all of the eggs are laid between sundown and midnight, however, it is not uncommon for a few moths to continue ovipositing until daybreak. Observations on caged specimens indicate egg laying is at its peak between

9:00 and 10:00 P. M.

The female gives the first sign of egg laying by fluttering around over the plants, apparently hunting for a suitable place to deposit her eggs. Upon alighting on a plant the tip of the abdomen is immediately curved downward and the apex of the ovipositor is used to explore every little crack and crevice. When a suitable place is found the moth comes to rest and deposits from 15 to 50 or sometimes more eggs. In most instances the moth places the eggs well down under the leaf sheath, into a deep crevice or in rolled or folded leaves where they are held in place and more or less covered by a sort of cement. Not infrequently the female will move about considerably while laying one batch of eggs, placing a few eggs in one crevice and a few more in another.

Although grasses, especially dead grasses, are preferred for oviposition the moths readily oviposit on many other plants particularly ragweed, pigweed, corn, dock, golden rod and in fact most any of the common fence row plants. Apparently the moths of Papaipema nebris do not posess an instinctive habit for depositing their eggs upon the food plants of their larvae and oviposition seems to be largely regulated by tactile stimuli. As previously mentioned a female about to oviposit uses the tip of her ovipositor to find a suitable place to deposit her eggs and unless she is able to find a suitable crack or crevice no eggs will be deposited. Fertile females placed in empty glass or tin containers refused to oviposit until a suitable medium was added. The addition of smooth paper or leaves would not induce oviposition, however, folded paper or rolled and folded leaves usually brought eggs. Dead leaves of corn, grass and weeds were greatly preferred for oviposition but in their absence many other substances, e. g., absorbent cotton, pieces of cloth, rough bark, empty pupae cases and the bodies of dead moths were used.

The moth's apparent preference for grasses may be accounted for in two ways. First the leaves of grasses with their encircling sheaths and rolled and folded blades are especially inviting to the moths; and second the moths most frequently spend the day hidden in the grass and since they are not very active it is to be expected that many of them will remain there to deposit their eggs.

Length of the Oviposition Period.

The preoviposition period varied from one to seven days and averaged 3.8 days. The time of mating greatly influenced the length of the preoviposition period. Unfertilized females usually hold their eggs until just before death, when a portion of them may be deposited. When females five or six days old were mated oviposition usually began the same day or the day following mating. Variations in temperature did not materially affect the length of the preoviposition period.

The oviposition period varied from four to twenty-three days and averaged 10.88 days. The moths do not always lay eggs every day during the oviposition period but as a rule a female that has once begun to lay will deposit a few eggs each day until near the end of the period, when a few irregular skips occur. The length of the oviposition period is closely correlated with the length of adult life and is therefore greatly influenced by the environmental factors which the longevity of the moth (temperature and water supply).

The post-oviposition period varied from none to nine days and averaged 2.44 days. Nineteen out of eighty-five females laid eggs during the day on which death occurred.

Number of eggs laid.

The daily rate of oviposition varied with different females and from day to day for each individual. Daily egg production varied from a minimum of 6 to a maximum of 735 eggs. In most cases the moths produce very large numbers of eggs (200-500 daily) for the first three or four days of the oviposition period after which there is usually a gradual decline in the number of eggs laid during each succeeding day. However, a few moths have one or two days of light egg deposition preceding the peak, a few do not reach a peak until late in the oviposition period and a few have more than one peak.

The number of eggs deposited by a moth during the whole life varied from 75 to 2199 and averaged 879. The size of the moth and length of adult life are the more important factors in determining the total number of eggs that will be produced. Since the ovaries always contain some immature eggs in which the yolk has not yet been formed it will be readily seen that maximum egg production can only be expected from those moths which live a full span of life.

## Longevity.

The length of life of the moths is determined almost entirely by biotic conditions, especially by temperature and water supply. During hot weather the moths have a high rate of metabolism, the rate of egg production is high and the length of life is comparatively short (8-10 days), whereas during cold weather the rate of metabolism is reduced and the moths are much longer lived (20-30 days). Moths deprived of water invariably died in less than ten days and except during very cold weather most of them died within four or five days. Moths which received sugar water, or diluted honey solution lived no longer than moths fed pure water.

Adult males lived from 2 to 34 days and averaged 16.6 days; adult females lived 3 to 36 days and averaged 17.1 days.

## Food of the Moths.

In the field moths were frequently observed sipping dew from leaves and they were occasionally observed taking nectar from clover and mint blossoms. It was also observed that moths in captivity fed readily upon either pure or sweetened water, when it was sprayed upon the foliage in their cages. In all cases the searching moths appeared to come upon their food supply by chance rather than by a response to some external stimulus. Unfed moths placed only a few centimeters away from water or sugar solutions did not seem to know that it was there and apparently they were not able to orient themselves and move toward the food. In the field no moths were ever attracted to sweetened baits.

## General Habits

During the day the moths are usually very quiet, remaining almost immovable in well concealed places such as tall grass, or thick weeds. The moths usually rest with the head downward and the wings tightly folded over the body and the supporting stem. When disturbed they may respond with a short sluggish flight but more often they feign death. Handling or proding with a pencil may or may not cause the insect to show signs of life. Ordinarily they will not move unless considerable pressure is applied. If rolled upon their backs they remain motionless for several moments, usually until after the observer has gone away.

Shortly after sundown the moths become somewhat active and begin to flutter about among the plants. Their flights are short, sluggish and of an erratic zig-zag character. During the first hour of activity the entire attention of the moth is given over to feedin after which the females begin to oviposit and the males apparently alternate between feeding and searching for mates.

There are occasional published records of the moths of Papaipema nebris being attracted to lights but never in very large numbers. W. B. Turner (48) reports the collection of 3 males of P. nebris in a total catch of 3,152 moths.

## SEASONAL HISTORY

The stalk borer is a typical one generation insect and there is very little variation in its seasonal occurrence. The eggs are laid on the leaves of grass and weeds during the late summer and early fall months (Aug. 20 -- Oct. 15.) These eggs overwinter on the plants and hatch the following May or June. The young larvae make their way into the young grass and weed plants where they feed until they kill or outgrow their host, when they migrate to new and larger stemmed plants. Transformation to the pupa stage takes place in the larval feeding burrow or in an especially constructed cell just below the surface of the soil. The moths emerge during late August and September and deposit their eggs on the leaves of dead grasses and weeds, where they remain until the following spring.

## NATURAL CONTROL

The abundance of the stalk borer is greatly influenced by several natural factors. Climatic conditions, birds, insectivorous mammals, insect parasites and preditors and diseases all play an important part in reducing the numbers of this insect.

### Climatic conditions

Hot dry weather near the end of the incubation period prevents many eggs from hatching and kills many newly hatched larvae, on the other hand heavy rains during the same period results in the drowning of many young caterpillars. Dry dusty weather during May and June destroys many first, second and third instar larvae, through dehydration, as they are forced to attemot migrations through the dry dust. Sudden changes from very cold to warm and extreme cold temperatures during the winter destroys some over-wintering eggs.

The weather also affects the borer population by its influence on plant growth and on the activity of parasites and disease organisms.

### Birds

In late summer and early fall many corn, ragweed, and other plants may be found with the main stalks shattered by numerous ragged angular holes made by the downy woodpecker (Dryobates pubescens L.) and allied species in their search for the borers. In small areas such as gardens and fence row infestations these birds often destroy as many as 80 per cent of the borers.

The robin, blackbird, bobwhite and brown thrasher, were frequently observed to visit infested fence rows for their meals. On several occasions, when attempting to build up a heavy infestation in a limited area by liberating many half-grown larvae, the writer observed that as soon as he walked away the robins, blackbirds and blue-birds rushed in and devoured most of the caterpillars before they could enter the plants and it was necessary for someone to remain in the vicinity for one or two hours so that the larvae could become established before the birds arrived.

The following birds have been observed more or less commonly feeding in areas infested by the stalk borer and those species marked with an asterisk have been observed feeding upon the larvae.

*Bobwhite or quail (_Colinus virginianus_).

Yellow-billed cuckoo (_Coccyzus americanus_)

*Downy woodpecker (_Dryobates pubescens_).

Red-headed woodpecker (_Melanerpes erythrocephalus_).

Flicker (_Colaptes auratus_).

Kingbird (_Tyrannus tyrannus_).

*Blue jay (_Cyanocitta cristata_).

Bobolink (_Dolichonyx oryzivorus_).

Cowbird (_Molothrus ater_).

*Red-winged blackbird (_Agelaius phoeniceus_).

*Meadow lark (_Sturnella magna_).

*Blackbird or grackle (_Quiscalus quiscula_).

Catbird (_Dumetella carolinensis_).

*Brown thrasher (_Toxostoma rufum_).

*Robin (_Planesticus migratorius_).

*Bluebird. (_Sialia sialis_).

Mammals

The skunk (_Mephitis nigra_ Peale & Beauw.) frequently digs holes at the bases of infested plants where it is searching for food and it must be considered as a destroyer of larvae and pupae.

The short-tailed shrew (_Blarina brevicauda_ Say.) is also a destroyer of the larval and pupal stages of the borer. These little animals frequently have many burrows or runways in grassy fence rows and where these runways are numerous one has difficulty in finding live larvae or pupae even though the plants above had been very heavily infested. Larval head capsules and fragments of pupa cases can frequently be found in digestive tracts of the shrews.

Moles and field mice frequently destroy many larvae and pupae in the vicinity of their burrows and nests.

## Predatory Insects.

### Coleoptera

Among the predacious insects attacking the borer the lady-bug beetles (Coccinellidae) and the ground beetles (Carabidae) are of greatest importance. It is important to note that these predators are active at a time when they are least in competition with the other parasites and preditors. The coccinellids are working early in the spring before the parasites appear and the carabids attack the mature larvae that have apparently escaped parasitism and are about to pupate.

The coccinellid beetles especially *Megilla maculata* De G., *Hippodamia convergens* Guer., and *Coccinella* novemnotata Hbst. although small and not especially ferocious appear at a time when they are able to destroy a great many borers. The adult beetles emerge from hibernation early in the spring when food is scarce and as a result they feed to considerable extent upon the overwintering eggs of the stalk borer and other insects. Later in the season they attack the first and second instar larvae but as a rule third and fourth instar larvae are able to fight them off and escape. Since the beetles normally hibernate in protected grass lands and fence rows where the stalk borer eggs are most abundant it is to be expected that they will destroy a great many of them. The following list of the common coccinellids were found hibernating in grass lands heavily infested with Papaipema eggs. Those marked with an asterisk were observed feeding upon the eggs.

*Megilla maculata De Geer.

*Hippodamia parenthesis Say.

Hippodamia 13-punctata Linn.

Hippodamia glacialis Fabr.

*Hippodamia convergens Guer.

*Coccinella 9-notata Hbst.

Coccinella trifasciata Linn.

Coccinella sanguinea Linn.

*Coccinella transversoguttata Fald.

*Adalia bipunctata Linn.

Chilocorus bivulnerus Muls.

Several species of carabids feed upon the larvae and pupae of the borer. The "fiery hunter" (Calosoma calidum Fab.) (Fig. 19), the largest and most ferocious of the carabids attacking the borer, is very active and is capable of destroying several mature larvae daily. Full grown larvae and adult beetles normally consume about one full grown caterpillar each day but apparently they are always ready for a fight and they will attack the catepillars almost as fast as they come to them. Newly emerged adults in cages, have been observed to kill 12 full grown borers in one day. It is unfortunate for the stalk borers that these hostile larva are becoming full grown and the hungry adults are emerging about the same time that the stalk borers are entering the soil to pupate.

Pasimachus elongatus Lec. a large black carabid with a blue margin on the thorax and elytra is very common in fence rows especially in loamy soil and where there is a moderate amount of trash. The immature stages have not been observed but the adults destroy many borers.

Scaraties subterraneus var. substriatus Hald., a large black beetle, was common in grass lands and fence rows. Like the Calosoma beetles the adults were ferocious and destroyed many caterpillars that happened to cross their path.

Several other species of carabids including, Dicaetus elongatus Bon., Evarthrus colossus Newm., E. sodalis Lec., Galerita janus Fab., and Harpalus Caliginosus Fab. have been observed to attack the borers but they are slow to act and are not to be considered as important predators.

Larvae of one of the fire flies (Chauliognathus pennsylvanicus De G.) was frequently found in Papaipema burrows, and in two instances they were observed attacking half grown borers. They were also observed to attack parasite pupae and their value as predators is somewhat questionable.

Hemiptera.

Five species of Hemiptera were found feeding upon Papaipema larvae and eggs.

During late May and early June adults of Triphleps insidiosus Say were frequently observed feeding upon the eggs and newly hatched borers. One Triphleps devoured nine Papaipema eggs in thirteen minutes but it was then apparently satisfied and no further feeding had occurred at theend of an hour when observation of it was discontinued.

The pentatomid, Podisus maculiventris Say, is the most valuable of the predacious Hemiptera attacking the stalk borer. Half grown nymphs and adults are frequently found with the flaccid remains of a half grown borer hanging on their beaks.

Adults of the nabid Nabis ferus Linn., and the reduviids, Sinea diadema Fab., and Zelus exsanguis (Stal.), attack the half grown larvae but the more nearly mature caterpillars are not molested by these bugs.

Chrysopidae.

Larvae of Chrysopa oculata Say have been observed feeding upon Papaipema eggs in the fall and in late spring. Caged specimens somewhat reluctantly attacked newly hatched larvae. It is very doubtful if they attack larvae in the field.

Hymenoptera.

Two species of ants, Solenopsis molesta Say and one undetermined species, frequently attack migrating larvae. As a rule several ants attack a single larva and although it may put up a good fight for a short time it is finally overpowered and carried away by the ants.

PARASITES.

Diptera

Masicera senilis Mg. (M. myoidea R. D. of Coquillett) is by far the most valuable of all the parasites of Papaipema nebris. In many localities this fly parasitizes as high as 70 per cent of the borers. The adults deposit living larvae on the host plant, usually near the entrance to the tunnel and it is up to the young maggot to find its host. Upon finding a borer the maggot attaches its self to the caterpillar and quickly burrows through the skin of the host. The maggot feeds within the body cavity of its host until the borer is nearly full grown, usually in the last instar, and then rapidly consumes most of the body tissues. After this the maggot makes its exit from the empty larval skin and within a few hours forms its puparium. The length of the pupal stage varies from 10 to 21 days and averages about fourteen days.

Adult emergence extends over a rather long period of time, beginning July first and continuing up to September fifteenth. Apparently this species passes the winter in the larval stage in some alternate host.

Usually but one fly emerges from a single host; however, the emergence of two flies is fairly common and in a few cases three flies have been reared from a single host. In cases where more than one fly developed in a caterpillar they were usually smaller than the others.

Pupation occurs either in the feeding burrow of the host or in the soil. Euptromalus dubius (Ashm), Plesignathus sp., and Perilampus hyalinus Say were reared as hyperparasites from the puparia of M. senilis.

Winthema quadripustulata Fabr., a common parasite of armyworms and cutworms, has been reared from Papaipema larvae and pupae on frequent occasions. This species is not a consistent parasite of Papaipema and apparently it only attacks the borer when other hosts are scarce or after the fly population has been built up during an armyworm or cutworm outbreak. However, when they do attack the borer they frequently parasitize from 12 to 21 per cent of the caterpillars. This percentage would undoubtedly be increased but for the fact that this species deposits eggs, usually on the thorax of the host, and the borers are therefore only susceptible to attack during migration periods.

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Muscina stabulans Fall. was reared from Papaipema larvae in small numbers each season and many puparia of this species were found within the feeding burrows of the borer. A few of these were reared from most all large field collections of host larvae.

Gymnochaeta ruficornis Will., a large tachinid fly, is a common parasite of last instar larvae. Just about the time a larva might be expected to pupate it frequently assumes a swollen appearance in the mid-body region and in a short time a large maggot penetrates the integument. This species hibernates as a pupa within the feeding burrows of the host or in the soil. The adults emerge the following May.

Lixus variabili Coq. Three specimens of this fly were reared from Papaipema larvae. The adults emerged July 15, 1928.

Sarcophaga helicis Tns. and Sarcophoga cimbicus Tns. were reared in small numbers from Papaipema larvae.

Hypostena variabilis Coq. and Exorista sp. were reared from Papaipema larvae by Washburn (50) in Minnesota but they have not been reared in Iowa.

Hymenoptera.

Apanteles papaipemae (Mues.) the most common hymenopterous parasite frequetly parasitizes as high as 38 per cent of the borers but the average would be much lower varying from eight to fourteen per cent. The parasite larvae emerged from the host just prior to the time that it might be expected to pupate, usually after it has left the plant and entered the soil, however, they occasionally come out while the host is still in its feeding burrow. Within a few hours the larvae spin their white cocoons which are arranged parallel to one another and bound together in a compact mass. The adults emerge during July and August.

Microbracan furtivus (Fyles) is less common than the preceding species but was reared from stalk borer larvae collected from several different localities. The larvae spin their cocoons during September but the adults do not emerge until the following May. Microbracan caulicola Gahn, a common parasite of Pyrausta larvae was reared from one Papaipema larva.

Microplitus gortynae Rly. was common in all localities and is probably the second most important hymenopterous parasite of the stalk borer. From 8 to 33 parasites emerged from a single host the average being 21.4. The parasite larvae usually emerge from the host before it leaves it feeding tunnel and soon spin their characteristic ribbed cocoons beside the dying host. The winter is passed in the larval stage and pupation occurs during April or May. The adults emerge during May and June.

Lissonota brunnea (Cress) a large ichneumon parasite was reared in large numbers. Adults emerged from overwintering pupae during April. During the warm hours of the day and when placed in a heated room the adults were very active but when the temperature dropped below 50° F. they became quite sluggish, however, they were still able to show feeble movements of the legs and antennae at 30°F. It seems probable that there is a spring generation on some alternate host.

*Amblyteles jucundus* (Brulle), another large *ichneumon*, was reared from *Papaipema* larvae but in smaller numbers than the preceding species. Adults emerged during August and a few in September.

In addition to the hymenopterous parasites of the stalk borer mentioned above the following species have been reported in literature: *Microbracon lutus* (Prov.), *Sagaritis oxylus* (Cress.), *Amblyteles lactus* (Brulle), and *Amblyteles orpheus* (Cress).

## Diseases

Many borers were killed by wilt disease (unidentified). Invariably, when large numbers of borers were placed in a common receptacle and then isolated and reared individually a large percentage of them died of this disease. Very soon after death the bodies became discolored, changing through brown to black. Within a day the body contents was reduced to a dark colored liquid which gave off a very foul odor.

Fourteen larvae were killed by a fungus, *Cordyceps* sp.; larvae killed by this disease developed long white fruiting bodies a few days after death.

Another fungus, Metarrhizium anisopliae (Metsch.) Sorok., was quite common on both larvae and pupae. Within a few hours after the death of the larva or pupa a white fungus growth appeared through the spiracles and in a short time the body was covered with a green and white fungus growth. Later the whole mass became green.

## Artificial Control

The control of the stalk borer calls for preventive rather than remedial control measures. In fact after a field of corn, grain, potatoes, or any other crop of low cash return is found to be infested there is very little that can be done except to keep the plants in a healthy growing condition and attempt to offset the effect of the borers.

## Weed Control

It has been pointed out that the largest borer populations occur in fields and fence rows containing many large stemmed weeds, especially, giant ragweed; and that pure stands of grass, clover and other small stemmed plants will not maintain a borer infestation. It, therefore follows logically that the elimination of ragweed and other large weeds from the fence row is the most important single step in controlling the borer.

## Mowing

Under certain conditions mowing of infested fence rows and waste lands may prove benificial but ordinarily mowing when the borers are active will increase the infestation in adjacent fields. However, mowing during the second week in August will remove the hiding places of the adults and render the locality undesirable for oviposition. If mowing earlier in the season is to be effective it will be necessary to remove the cut grass and weeds before they become entirely wilted. One farmer who makes a practice of mowing the roadside around his farm and hauling the hay in for feed before it is thoroughly cured states that he has observed hundreds of half-grown borers come out of the grass and drop to the ground after the load had been hauled to the barnyard.

## Burning

Burning fence rows and infested grass lands between November first and May first, destroys the overwintering eggs and is one of the most practical means of control. Two years experiments with burning show that this method will reduce the borer population by 85 to 90 per cent, and that burning in the spring is slightly, more effective than burning in the fall. This is apparently due to the fact that dead leaves of corn and weeds on which many eggs had been deposited were blown into the control plots during the winter and in that way the plots which were burned in the fall were reinfected.

## Miscellaneous treatments.

After the borer has once entered a valuable plant the only means of saving the plant is by slitting the stem lengthwise and removing the offending caterpillar. This method will be found very helpful provided care is exercise to prevent destruction of the vascular system by cross section cuts. Where the plants are seriously injured and the tops badly wilted it is advisable to remove the plant and destroy it.

In many cases it is possible to kill the borer and save the plant by injecting one-half teaspoonful of chloroform, carbon tetrachloride or carbon disulphide into the entrance hole and then plugging the opening with moist clay.

Valuable plants may be protected by tanglefoot barriers. The tanglefoot may e applied direct to the base of the plant but in most cases it seems preferable to surround the plant with a tin or cardboard collar four or six inches high and apply the tanglefoot to the upper two inches of this collar. If this type of barrier is to be effective the tanglefoot should be sticky at all times and it is important that the upper portions of the plants do not come in contact with other plants which are not protected.

## THE SPINDLE WORM
## *Achatodes zeae* (Harris).

The spindle worm (*Achatodes zeae*) was first described and reported as a corn pest by T. W. Harris in 1841 (25). Since that time occasional references have been made to it in literature. It is now generally conceded that the spindle worm is seldom found in corn or other cultivated crops except along the margins of fields of a heavily infested growth of elder (*Sambucus*).

### Descriptions

#### Egg

Circular in cross section, depressed at both poles; yellow when first laid but soon turning to yellowish gray; exo-chorion sculptured.

Equatorial diameter 0.6 mm., polar diameter 0.33 mm.

#### Larva

Body cylindrical, robust, without secondary hairs, yellowish white in color, Head, thoracic and anal shields, and pinocula glossy black; anal shields with six prominent spines on caudal margin.

#### Pupa

Moderately slender, cylindrical, slightly tapering to anal extremity, reddish brown in color. Head with two prominent rounded projections. Cremaster without long spines but with six short spines. Length 15-20 mm.

#### Adult

The adult was described as follows by T. W. Harris: "The fore wings are rust-red: they are mottled with gray, almost in bands, uniting with the ordinary spots, which are also gray and indistinct; there is an irregular tawny spot near the tip, and on the veins there are a few black dots. The hind wings are yellowish gray, with a central dusky spot, behind which are two faint, dusky bands. The head and thorax are rust-red, with an elevated tawny tuft on each. The abdomen is pale brown, with a row of tawny tufts on the back. The wings expand nearly one inch and a half."

## LIFE HISTORY AND HABITS

### Egg

The normal length of the egg stage is about nine or nine and one-half months. Eggs laid during late July do not hatch until the fore part of the following May.

### Larvae

The overwintering eggs hatch about the time the elder is sending out its first leaves and the newly hatched larvae usually burrow into the tips of the slowly unfolding leaves. Within a few days they work their way into the petiole of the leaf and then down into the main stem. By the time the young shoots from the ground are six to ten inches tall second and third instar larvae may be found in the main stems. When the borers outgrow the stems in which they are working they migrate to other plants. The entrance to the burrow is usually fairly low and the burrows almost invariably proceed upward from the entrance. Larval life varies from 40 to 65 days in length and during this time the borer passes through from six to eight larval instars. When growth is completed the larvae abandon their feeding burrows and seek dead shoots, dry stubs or dead weeds in which they prepare a pupal chamber.

### Pupa

Pupation occurs in the specially constructed pupal chambers. In heavily infested thickets as many as six or eight pupae may be found in a short stem.

The length of the pupal period varied from 14 to 31 days and averaged 19 days.

### Adults

The adults are nocturnal and seldom seen during the day. Mating normally occurs the first or second night following emergence and oviposition usually begins the night following mating. Each female deposits from 140 to 480 eggs in cracks, around leaf scars and under bits of broken bark of old elder plants.

### Seasonal History

The spindle worm has but one generation a year. The overwintering eggs hatch during the fore part of May. By July first practically all of the larvae have pupated and by August first the moths have emerged laid their eggs and died.

## Control

In localities where the spindle worm is injurious it may be controlled by removing the elder plants.

## THE LINED-CORN BORER
*Oligia fractilinea* (Grote)

The lined corn borer is a comparatively rare pest in Iowa, or at least it has successfully avoided attracting attention. It was first found by the writer in Franklin County, June 26, 1926. Since that time larvae have been collected in Wright, Hamilton, Black Hawk, Marshall, Story and Boone Counties, but never in very large numbers. In most cases the larvae were taken from corn which had been planted on spring plowed sod. The larvae ~~which~~ are nearly one inch long, yellowish white in color and marked with four longitudinal, dull brown stripes. They usually enter the plant by climbing to the top and working downward through the throat of the plant. Pupation occurs in the soil during late June or early July and the moths emerge the latter part of July or the fore part of August. There is presumably but one generation a year, the eggs being laid largely in timothy sod during August.

## THE SMARTWEED BORER AND THE LOTUS BORER.
*Pyrausta ainsliei* Hein.
*Pyrausta penitalis* Grote.

The smartweed borer (*Pyrausta ainsliei*) and the lotus borer (*Pyrausta penitalis*), two close relatives of the

the European corn borer, are common inhabitants of smartweed (Polygonum spp.) in Iowa. They are never injurious to corn but during the late summer months many larvae of both species seek corn stalks, large stemmed weeds and other suitable plants as shelter for the winter. About the middle of May the overwintering caterpillars pupate within their winter quarters and the moths begin to appear about two weeks later. They do not enter the corn plants again until it is time for larvae of the last generation to prepare for hibernation.

## SUMMARY

1. The four-lined borer, Luperina stipata (Morr.), the stalk borer, Papaipema nebris (Gn.) and the spindle worm, Achatodes zeae (Harris), are native insects, normally feeding upon weeds and grasses, but occasionally causing considerable damage to corn.

2. All of these species have but one generation each year. The overwintering eggs hatch during late April or early May and after a short growing period the larvae pupate. The moths emerge during mid-summer and deposit the eggs for the next years brood.

3. The life history and habits of each species is given in detail.

4. Natural enemies play an important part in holding these insects in check. The more important parasites and predators are listed and some notes on their bionomics are given.

5. The elimination of the natural host plants of the borers from the fence row flora and the burning of infested fence rows and grass lands between November first and April first are recommended as means of control.

6. The smartweed borer, Pyrausta ainsliei Hein, and the lotus borer, Pyrausta penitalis Grote, although not injurious to corn are frequently found seeking shelter in corn stalks during the fall and winter months.

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Plate I.

_Luperina Stipata_ (Morr.).

Figure 1.

a. Adult female.

b. Adult male.

c. Egg.

d. Larva.

e. Pupa.

f. Injured corn.

g. Larva in subterranean burrow.

h. Larva entering plant.

i. Pupa in cell.

j. Injured _Spartina_ sod.

Plate I.

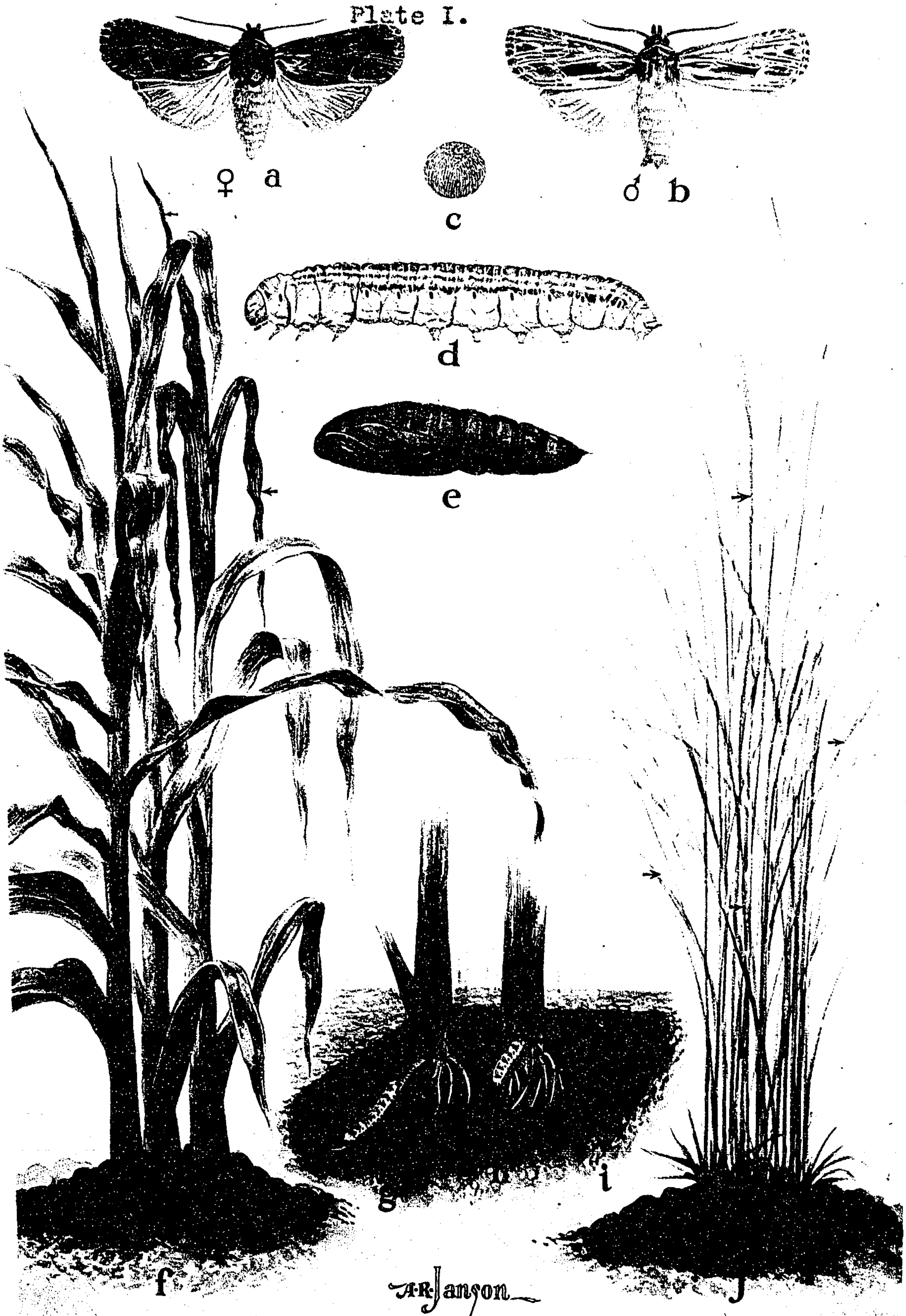



Figure 1.

Plate II.

Luperina stipata (Morr.)

Figure 2. A field of corn seriously damaged by the four-lined borer.

Figure 3. Corn plants showing characteristic injury produced by the four lined-borer.

Figure 4. Eggs of the four-lined borer on grass stem with outer sheath partly removed.

Figure 5. Pupa of the four-lined borer, twice natural size.

Figure 6. Larva of the four-lined borer in pre-pupa stage, natural size.

Figure 7. Adult moth of the four-lined borer, twice natural size.

Plate II.

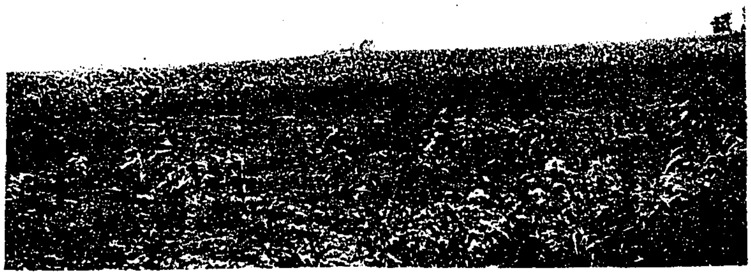
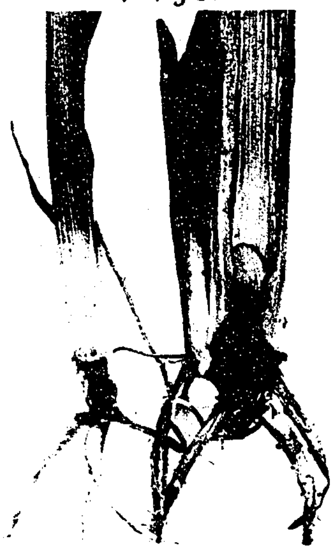


Figure 2.

Figure 4



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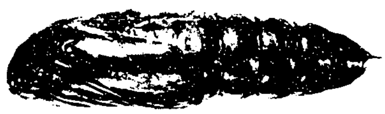

Figure 5.

Figure 6.

Figure 7.

Plate III.

Luperina stipata (Morr.)

Figure 8. Setal pattern of mature larva of the four-lined borer.

Plate III.

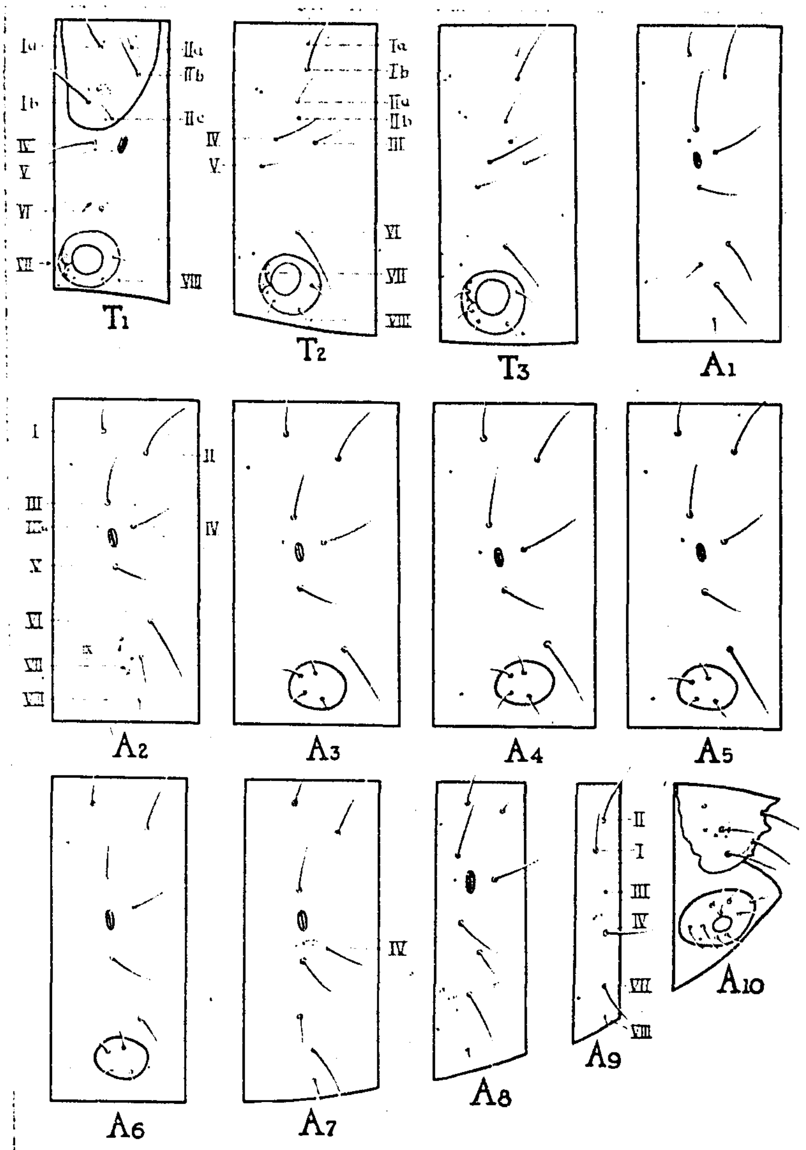


Figure. 8.

Plate IV.

Luperina stipata (Morr.)

Figure 9. Head capsule of sixth instar larva of the four-lined borer, showing setal arrangement: above, dorsal view; below, lateral view.

Figure 10. Fore and hind wing of the four-lined borer, showing wing venation.

Figure 11. Pupa of the four-lined borer; A, ventral view of female; B, dorsal view; C, lateral view; D, ventral view of the abdominal segments of a male.

Plate IV.

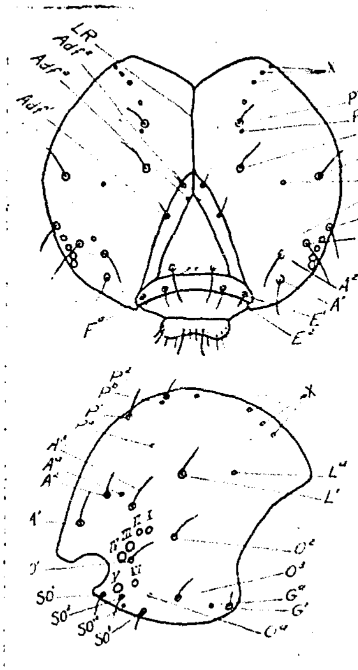

Figure.9.

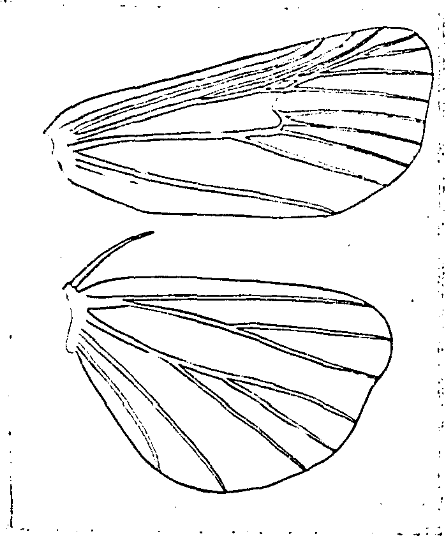

Figure.10.

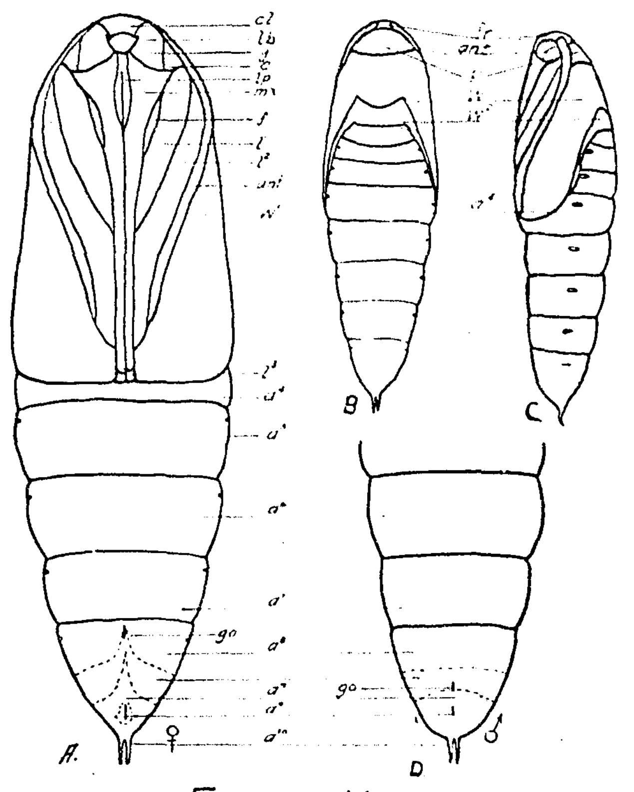

Figure.11.

Plate V.

Luperina stipata (Morr.)

Figure 12. Graph: showing the effect of food (using various parts of the corn plant as food) upon the widths of successive head capsules.

Figure 13. Graph: showing the effect of temperature upon the width of successive larval head capsules.

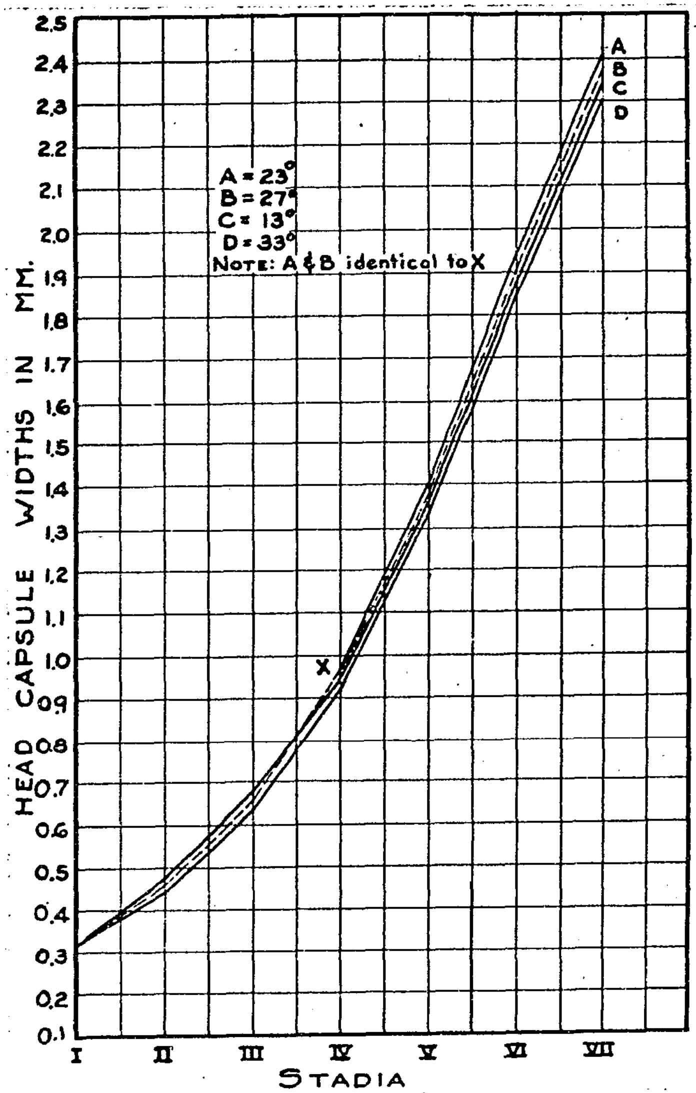


Figure 13

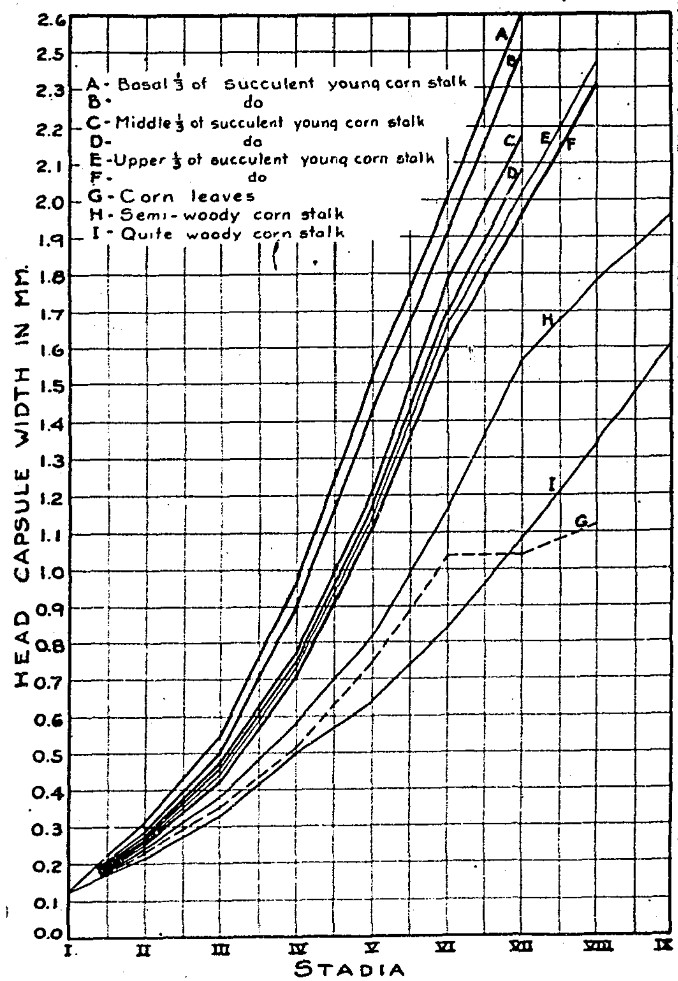


Figure 12.

Plate V.

Plate VI.

Luperina stipata (Morr.)

Figure 14. Graph: showing the effect of temperature upon the duration of the larval stadia.

Plate VI

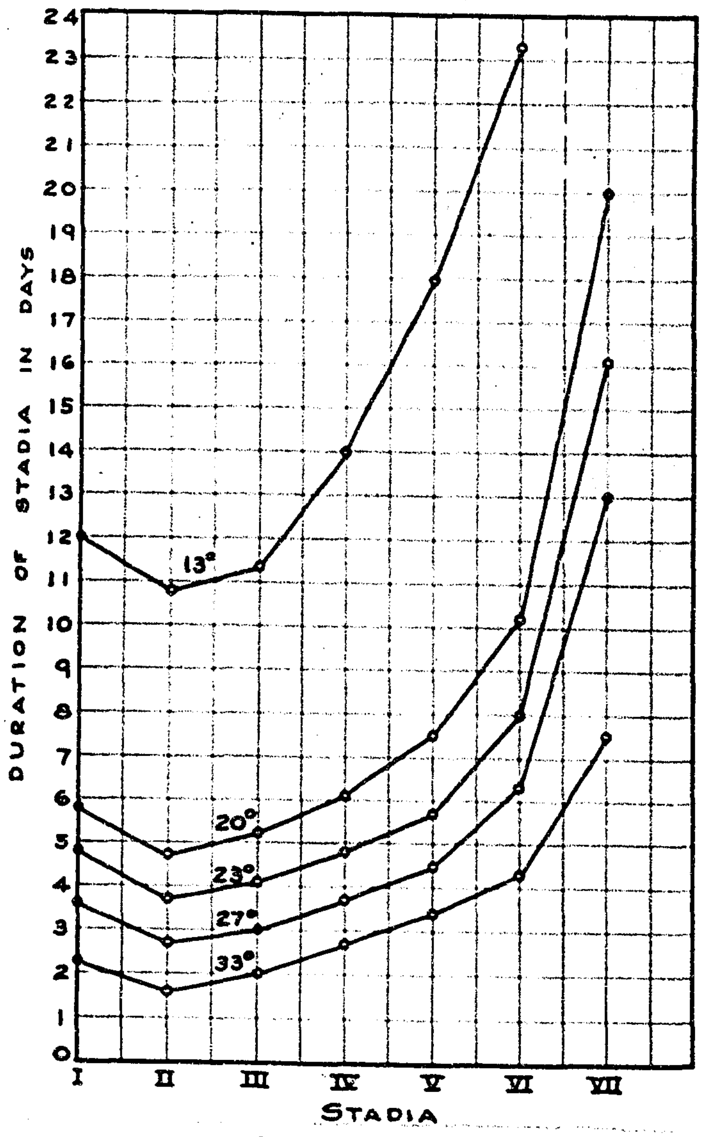


Figure. 14.

Plate VII.

<u>Luperina Stipata</u> (Morr.)

Figure 15. Map: showing distribution of the four-lined borer in Iowa.

Figure 16. Chart: showing the seasonal history of the four-lined borer.

Plate VII

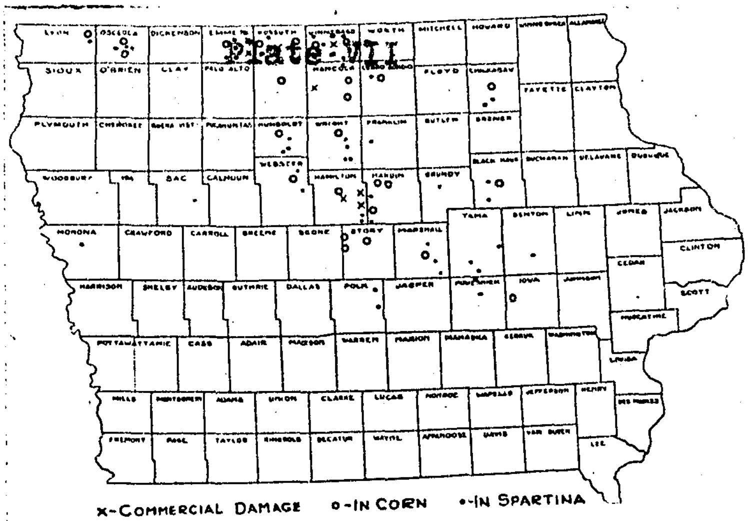


Figure 15.

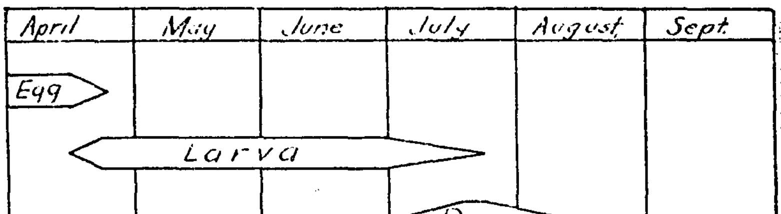


Figure. 16.

Plate VIII

*Luperina stipata* (Morr.) and *Papaipema nebris* (Gn.)

Figure 17. *Ectopimorpha* sp., and important parasite of the four-lined borer.

Figure 18. Parasitized larva of the four-lined borer and cocoons of *Microplitis gortynae* Riley.

Figure 19. The fiery hunter, *Calosoma calidum*, an enemy of the four-lined borer and the stalk borer.

Figure 20. *Scarates subterranean* var. *substratus* Hald., an important predator on the four-lined borer and the stalk borer.

Plate VIII

Figure 17.

Figure 18.

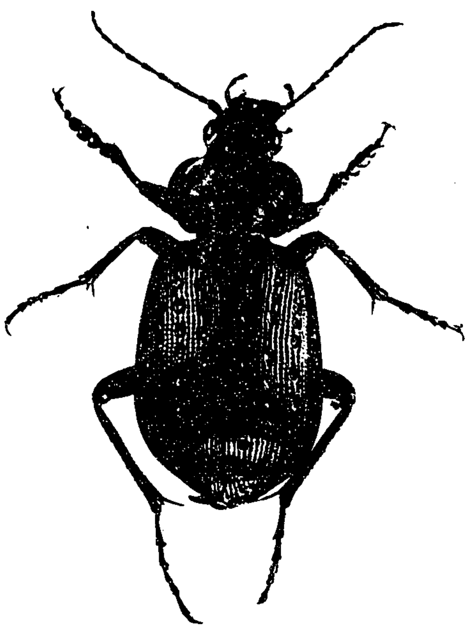

Figure 19

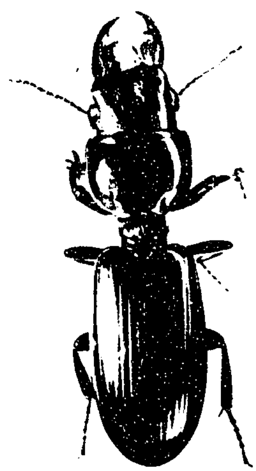

Figure 20.

Plate IX.

Papaipema nebris (Gn.)

Figure 21. Drawing: showing the stalk borer egg, larva, pupa, and adult stages, and characteristic injury to plants.

Plate IX

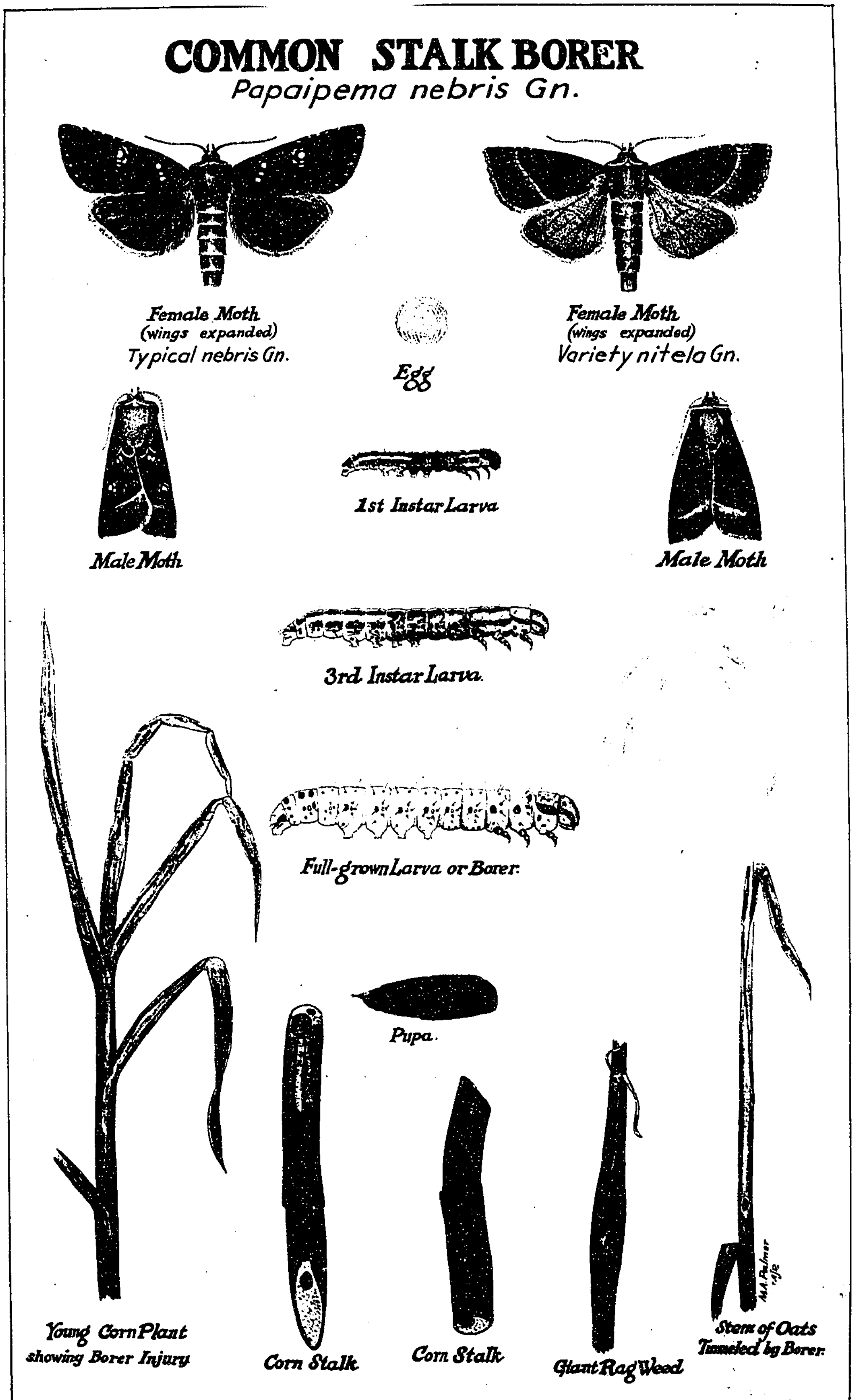


Figure 21.

Plate X.

Papaipema nebris (Gn.)

Figure 22. Corn plants showing characteristic injury produced by the stalk borer.

Figure 23. An ear of corn showing injury by the stalk borer.

Figure 24. A field of corn seriously damaged by the stalk borer.

Plate X.

Figure 22

Figure 23.

Figure 24.

Plate XI.

<u>Papaipema nebris</u> (Gn.)

Figure 25. Setal pattern of a mature larva of the stalk borer.

Plate XI.

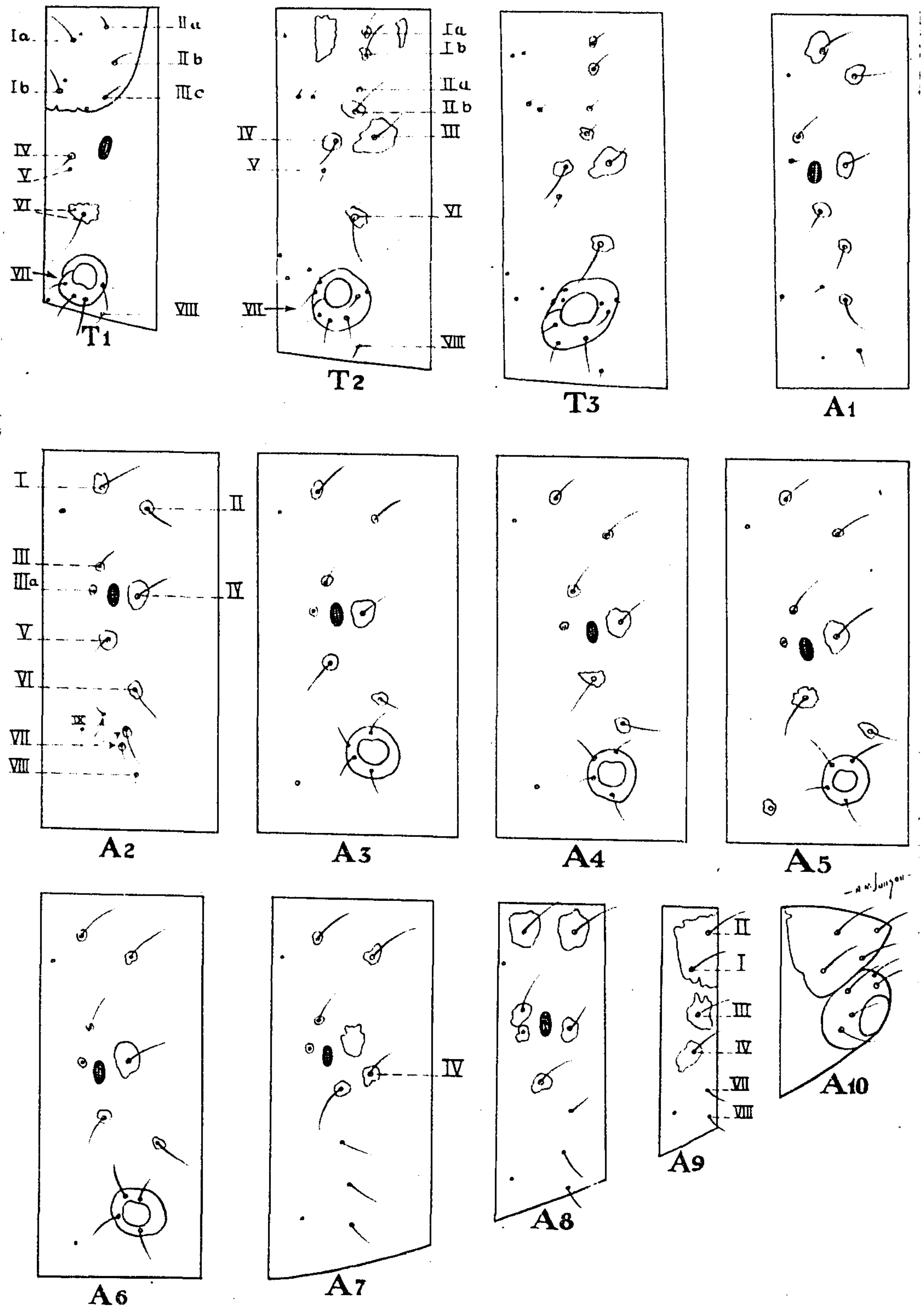


*Figure 25*

Plate XII.

Papaipema nebris (Gn.)

Figure 26. Head capsule of an eighth instar larva of the stalk borer showing setal arrangement; above, dorsal view; below, lateral view.

Figure 27. Pupa of the stalk borer: A, ventral view of female; B, dorsal view, C, lateral view of the abdominal segments of a male.

Plate XII

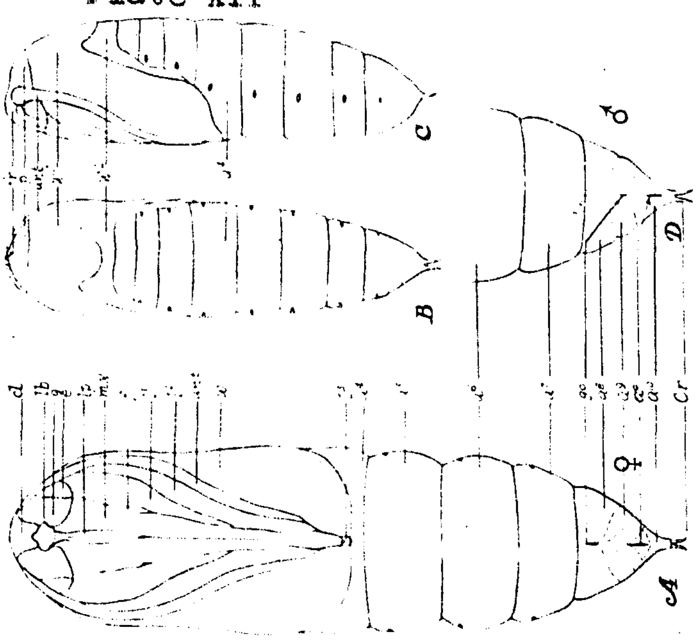

Figure 27.

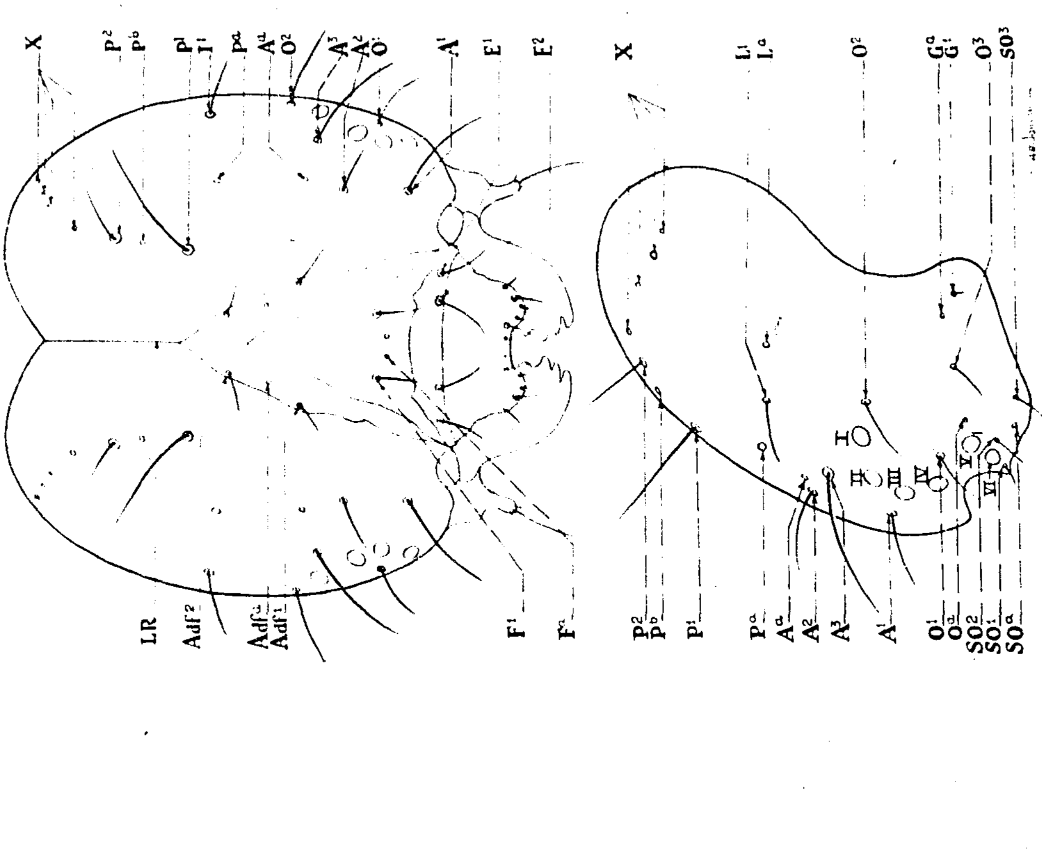

Figure 26

Plate XIII

*Papaipema nebris* (Gn.)

Figure 28. Eggs of the stalk borer, on grass leaves.

Figure 29. Ragweed stalks cut open to show larval burrows.

Figure 30. Stalk borer pupa in a corn stalk.

Figure 31. Stalk borer larva in a corn stalk.

Plate XIII.

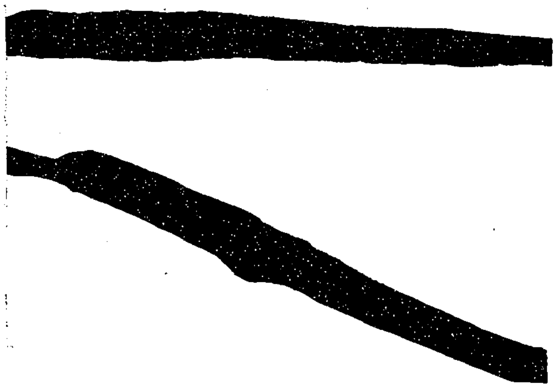

Figure 28.

Figure 29.

Figure 30.

Figure 31

Plate XIV

Papaipema nebris (Gn.)

Figure 32. Fence row with a heavy growth of giant ragweed. This type of fence row builds up a large borer population.

Figure 33. A fence row in winter. Many stalk borer eggs overwinter in such fence rows.

Plate XIV.

Figure 32.

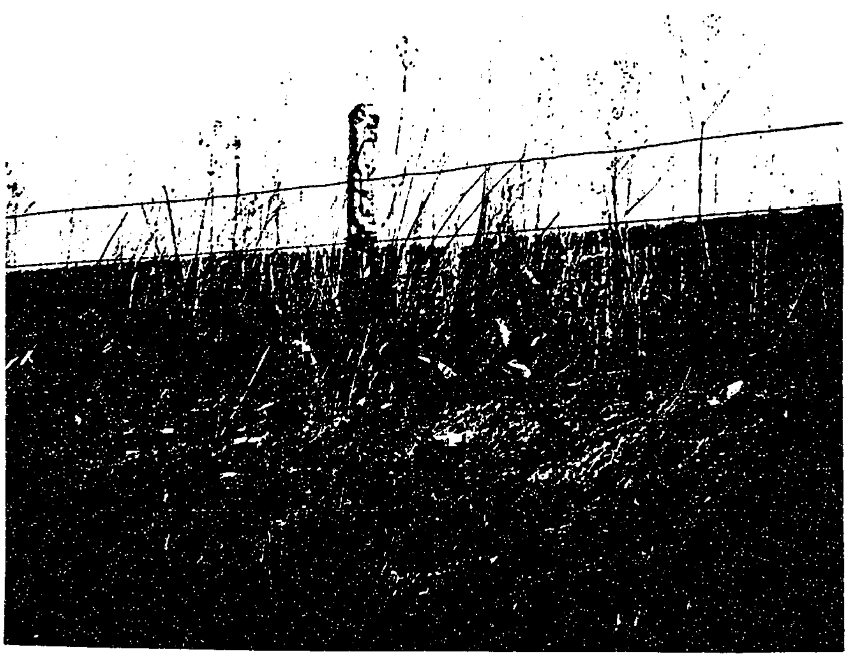

Figure 33.